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EDITORIAL.

ITEMS AND NOVELTIES.

The Belgian Government Prizes.—The following is the text of the official letter from the King of Belgium to the Minister of the Interior, establishing the grand governmental prize. It is published in the official column of the *Moniteur Belge*, of December 15th:

"MY DEAR MINISTER: Desiring to contribute, as much as is in my power, to the development of intellectual labor in Belgium, I hereby announce my intention to institute, during the continuance of my reign, an annual prize of 25,000 francs, designed for the encouragement of intelligence in workmanship. This foundation, in my opinion, should possess a double character. It should have for its object, firstly, to stimulate intellectual labor in our own country; and in the second place, it should call the attention of the citizens of other countries to questions of interest to Belgium, and in this way associate Belgium with the progress which the sciences, letters, and arts are making outside her domain.

"In consequence of this opinion, the prize which I hereby institute will be awarded upon the following conditions, and in the following manner:

"During the first three consecutive years it will be awarded to the best work published in Belgium, by a Belgian, upon subjects to be

designated beforehand, the award not to be made until five years after the announcement of the subject. The fourth year, citizens of other countries will be admitted to competition, and the prize will be awarded to the best work published either by a Belgian or by a foreigner, upon a subject of interest to Belgium, also announced in advance. In this way, every four years, a draft will be made upon the progress and the discoveries of other countries for the benefit of Belgium. The fifth, the sixth, and the seventh years, the prize will be again restricted to productions exclusively Belgian; the eighth year, those of other countries will be again admitted, and so on during each period of four years.

"A jury of seven members will be designated by the Minister of the Interior, acting in concert with myself, for the purpose of deciding upon the works presented. The subject matter of the *concours* being changed each year, the jury will also be modified every year.

"The jury, on the years when foreigners compete, will be composed of three Belgian, and of four foreign members of different nationalities. The president will be a Belgian. I do not believe that there will be found, among the savants of any country friendly to us, any who will refuse to assist us, or to decline to take their places with the Belgian jurors in Brussels.

"Not wishing to postpone for five years the execution of my purpose, I desire that, as a temporary arrangement, the first award of the prize shall be made during the September fêtes of the year 1878.

"For the first four years, the prize will be thus awarded: In 1878 (competition exclusively Belgian), for the best work upon our national history; in 1879 (also exclusively Belgian), for the best work on architecture; in 1880 (exclusively Belgian), for the best work upon the development of the commercial relations of Belgium; in 1881 (competition mixed), for the best work upon the methods of improving seaports situated upon low and sandy coasts like our own.

"Next year, the subject for which the prize will be awarded in 1882, will be announced, and so on; each year the subject will be announced for which the prize will be awarded five years thereafter. I beg of you, my dear Minister, to take the necessary steps to carry into immediate execution the plan of which I have now sketched to you the outline, and to receive anew the expression of my affectionate regard."

"LEOPOLD."

Brussels, December 3d, 1874.

Explosives as Sources of Power.—In considering the motive power of the future, it is impossible not to reflect upon the possible utilization for this purpose of explosive agents, such as gunpowder, the picrates, etc. They all may be considered as magazines of immense power, incomparably greater than the power stored up in any of the ordinary combustibles, such as coal or petroleum. In this view of the case, the following extract from a paper by M. Champion, an excellent authority upon the subject, becomes interesting:

"It is estimated that the explosive power of nitro-glycerin is equal to ten times that of gunpowder, and that half a kilogram (1·1 pounds) would lift from the ground and project a weight of 160,000 kilograms. The heat evolved in the reaction is about 1,282,000 calories for each kilogram. This same kilogram of nitro-glycerin, exploding in a closed space having a volume of one liter, develops a theoretical pressure of 243,000 atmospheres, a temperature of 93,400 degrees, and a quantity of heat equal to 19,700,000 calories.

"One liter of nitro-glycerin weighs 1·6 kilograms. In exploding in a space completely filled with it, as happens in a blast-hole in mining operations, or when operating under water, this substance develops a pressure of 470,000 atmospheres; a pressure eight to ten times that produced by the same volume of gunpowder.

"The heat thus developed being 38,000,000 calories, the mechanical labor produced, which is the equivalent of this, rises to the enormous number of more than sixteen thousand million kilogram-meters, a value five times that of the maximum value of gunpowder."

"A kilogram of coal contains about 8000 calories," says the *Revue Industrielle*, "each calory being equivalent, theoretically, to 120 kilogram-meters. Hence, the maximum mechanical work of 1·6 kilograms of coal would be 5,476,000 kilogram-meters; a quantity 3000 times less than is produced with the same weight of nitro-glycerin.

"Is not the imagination of the most enthusiastic inventor" it continues, "staggered in presence of these enormous numbers? What an answer, too, do these figures furnish to the pessimists who see in the exhaustion of our coal mines the extinction of the industries of the future! *In a single liter of nitro-glycerin there is stored up the enormous labor of* 5500 *horse-powers acting continuously for ten hours!*"

Japanese Paper.—In the Japan department of the Vienna Exhibition, a series of objects made from paper were exhibited which excited great interest. Among other articles, there were to be seen in this collection, handkerchiefs, towels, umbrellas, cloaks and other articles of dress, lanterns, etc.; and all made of paper, of a texture exceedingly firm. The manufacture of such paper is extremely complicated, and is almost unknown in Europe and America. The following facts in relation to it are taken from a Report recently made upon this subject to the Society of German Orientalists, by M. Zappe.

For the manufacture of their paper, the Japanese have used for centuries the bark of the *Broutonessia papyrifera*, which grows throughout almost the entire extent of the empire. The culture of the plant is very simple: old roots, cut into lengths of about four inches, are thrust into the ground so that about an inch projects above the surface. The first year these roots give a growth of shoots about a foot long, and the second year a growth of two to three feet. At the end of the third year the plant has a total height of nearly fourteen feet. The tenth month of each year these shoots are cut off on a level with the top of the root. Each shoot consequently yields five branches; so that at the end of five years there is formed a large, bushy tree, the branches of which may be used for the manufacture of paper.

The branches are cut for this purpose in winter. They are divided into pieces of twenty-eight inches in length, and these are heated in water until the bark is readily removed by the hand. This bark is then seasoned by exposure to the air, an operation which requires from two to three days at the ordinary temperature, and twenty-four hours only during high winds. After an immersion of at least twenty-four hours in running water, the bark is submitted to the action of a sharp cutting edge placed above a matting of straw; the object being to separate the two sorts of fibers of which it is composed; the exterior fibers, dark in color, "*saru kawa*," being used in the preparation of a paper of inferior quality, such as the *chiri gami*, or the *kizo suki*.

The finer varieties of paper are made with the interior fibers, called *sosori*. These are rolled together in balls of about thirty pounds weight, which are washed in running water, are then placed in flat tanks of water, and are withdrawn after a certain time and the water pressed out. They are then heated in a lye made from the ashes of

buckwheat bran, taking care to agitate them constantly with stirrers, until the liquid is brought to active ebullition. A new washing in running water deprives them finally of all impurities. They are withdrawn and subjected for twenty minutes to a beating upon a block of oak or cherry; after which they are collected into bales and placed in heaps, forming the material for the pulp.

During the fabrication of the paper, there is added to the liquid mass a little *tororo*, extracted from the root of the *hibiocus manihot*. In summer, rice-water is also added, in order to prevent the ravages of worms. The pulp thus obtained is subsequently made into paper by a process analogous to that employed in Europe for making paper from rags.

The variety called leather-paper is made by the superposition of several layers of the paper called *toza-senka*. These are first soaked in the oil of the yenoki (Cellis wildenowiana), then, after having subjected them to strong pressure, they are covered with a layer of lacquer.

Clothing is made with a paper called *shifu*. The sheets of this paper are cut into strips, more or less wide, according to the fineness of the material to be made. These are then twisted into threads by the fingers previously moistened with milk of lime. These threads are woven into cloth, either alone, or mixed with silk. The materials made of them can be washed, and have great strength.

Crape-paper is made with very firm sheets, which are first moistened with water, and over which is rolled, first lengthwise and then crosswise, a wooden roller, on which is engraved the design.

Besides the *Broutonessia papyrifera*, the Japanese employ also the *Edgeworthia papyrifera*, in the manufacture of paper. The mode of manufacture is identical with that which has just been described.

Very Resistant Glass, almost Malleable.—A manufacturer of Pont-d'Ain, M. de la Batie, has discovered a means of rendering glass almost malleable, and is about to erect a factory for the production of articles of this new glass. From his patents it appears that his process consists in annealing the glass while yet in a pasty state, at the time of its fusion and in the furnaces where it is made. This annealing should be effected in a liquid *ad hoc* and under special conditions. This operation, while it does not render the glass absolutely malleable, increases its resisting power about forty times. We have

seen, says the *Revue Industrielle*, an ordinary pane of window glass thus annealed, upon which was allowed to fall from a hight of six feet a five franc piece, without causing the least damage. The importance of this discovery in all branches of glass manufacture cannot fail to be very great. The new glass works of M. de la Batie will be established at Pont-d'Ain. A company has been formed with a capital of 250, 000 francs for the purpose of putting the invention into practical operation.

Bibliographical Notices.

TABLES FOR THE DETERMINATION OF MINERALS *by those Physical Properties ascertainable by the aid of such simple Instruments as every Student in the Field should have with him.* Translated from the German of Weisbach. Enlarged and furnished with a set of Mineral Formulas, a column of Specific Gravities, and one of the characteristic Blowpipe Reactions. By PERSIFOR FRAZER, JR., A. M., &c. 12mo., pp. 117. Philadelphia, 1875. J. B. Lippincott & Co.

The German student of Mineralogy is fortunate in having at disposition quite an array of convenient tables to aid him in his determinations. Of these Handbooks, or *Tafeln zûr Bestimmûng der Mineralien*, the works of Weisbach, Blum, v. Kobell, and Fuchs are perhaps the best known. Most of them, however, are only of value in the class room or the laboratory, or premise considerable practical acquaintance with crystallography. The work of Blum, for instance, is purely crystallographic; that of v. Kobell, though making a primary division into minerals with and without metallic lustre, identifies them solely by their chemical properties, while that of Fuchs combines the features of both. None of these works are well adapted to the wants of the student, prospector, or mineral collector when in the field and deprived of the convenient accessories of the laboratory. The wants of this large class have been recognized and admirably met in the Tables of Prof. Weisbach, which the translation of Prof. Frazer has made accessible to those who are not familiar with the language of the original.

In these tables the minerals are divided into three classes, which are readily determined by simple inspection, viz.: those of metallic lustre; those of non-metallic lustre which give a colored powder; and those of non-metallic lustre and colorless streak. The subdivisions which lead to the specific identification of the species are

founded, first on the test of hardness, which is then supplemented by the additional aids of the other physical properties, color, tenacity, crystallization, and cleavage.

Armed with the few simple paraphernalia, which the student or collector in the field is always supposed to carry—hammer, file, knife, streak-tablet, and magnifier—he is prepared, with the aid of this pocket book, to identify most of the minerals he may meet. We can cordially recommend the tables as highly useful and conveniently arranged, and trust, at the same time, that one criticism that we have heard passed upon them may find no grounds in a second edition, by the interpolation of a number of distinctively American species that are wanting in this one. W.

Franklin Institute.

SPECIAL MEETING.

HALL OF THE INSTITUTE, Dec. 7th, 1874.

The meeting was called to order at the usual hour, with the President, Mr. Coleman Sellers, in the chair.

The President stated the object of the meeting, and ordered the reading of the call on account of which he had authorized it.

The Secretary then read the following communication:

Hall of the Franklin Institute, Dec. 2, 1874.

Coleman Sellers, Esq., President Franklin Institute.—Dear Sir — The undersigned members request that you call a special meeting of the Institute on Monday next, 7th inst., to prepare for the Board of Managers at their meeting on the 9th inst., plans for the *immediate* augmentation of the Library and alteration of the Building.

(Signed by 21 members.)

The President thereupon pronounced the meeting ready to proceed with its special business.

The Actuary presented the following resolutions from the Library Committee, which had been passed at its meeting Dec. 7th, 1874:

Resolved, That the following resolutions be recommended to the Institute for adoption:

1st. That the Board of Managers be requested to make an appropriation to the Library Committee, which will enable it to make the library more nearly complete for the purposes of the Institute.

2d. That the Library Committee be authorized to sell such books as have no reference to the purposes of the Institute.

Mr. Wm. P. Tatham moved the adoption of the resolutions.

Mr. Joseph Willcox objected to the first resolution, that it was too indefinite, and that a sum of money should be appropriated; or at least a sum named as a limit.

Mr. B. H. Moore suggested that the sum to be appropriated might safely be left to the discretion of the Board of Managers.

Mr. Willcox moved to amend the first resolution by inserting that "the sum to be expended shall not exceed $10,000."

Mr. Tatham, in reply to an inquiry from the meeting, described the kind of books in the library proposed to be sold by the second resolution.

Mr. J. E. Mitchell doubted the expediency of spending so much money as $10,000 in the present location of the Institute.

Mr. Moore urged that the immediate expenditure of a respectable sum of money for the augmentation of the Library, was a matter of prime importance, but added that the Board of Managers was the proper authority to decide upon the sum to be thus expended.

Dr. J. S. Cohen wished to know what sum the committee had in view in their resolutions.

Mr. J. W. Nystrom, from the committee, named $2000 to $3000.

Mr. Cheney offered as a second amendment to the first resolution, that the sum to be appropriated be left to the judgment of the Board.

Mr. S. Lloyd Wiegand asked for information as to whether the general meeting was competent to order the appropriation of money, or whether its authority was not limited to the passage of a suggestion or recommendation to the Board. The President, in reply, read from the By-Laws the section referring to the functions of the Board, and explained that all authority in matters of finance was solely vested in the Board, and that it alone possessed authority to order the expenditure of moneys of the Institute.

The second amendment, which leaves the amount of money to be expended, to the discretion of the Board of Managers, was thereupon put to the meeting and was carried. As the first amendment was

neutralized by the passage of the second, it was withdrawn. The question upon the first resolution as amended was then put to vote, and carried.

Upon the second resolution, Mr. Hector Orr inquired whether the Board of Managers had the authority to sell any property of the Institute, without previous consent obtained from a meeting of the stockholders. The President read for the information of the meeting from the By-Laws, the powers of the stockholders.

Mr. Chas. S. Close remarked that if the Library Committee should report that a lot of useless material was taking up valuable space imperatively needed for useful purposes, no one would raise objection as to its sale, or inquire upon what authority it was disposed of.

Mr. Tatham said that the object of the Committee in presenting the second resolution was to get more space in the Library room.

Mr. Cheney amended the resolution by the clause, that "the proceeds of such sale be devoted to the improvement of the Library." The amendment was accepted on behalf of the committee by Mr. Tatham. The resolution as amended was offered to the meeting and carried.

The two resolutions as amended and adopted, read as follows:

Resolved, That the Board of Managers be requested to make an appropriation to the Library Committee which will enable it to make the Library more nearly complete for the purposes of the Institute, the sum to be thus appropriated being left to the discretion of the Board.

Resolved, That the Library Committee be authorized to sell such books as have no reference to the purposes of the Institute, the proceeds of such sale to be appropriated to the improvement of the Library."

Mr. Thomas Shaw referred to the privileges conferred upon the stockholders as being extraordinary, and inquired whether any alteration of the building was possible without their consent having been first obtained. The President decided that the consent of the stockholders was not needed.

Dr. Cohen referred to the necessity of having a printed catalogue for the library, and moved that the importance of this matter be urged upon the Library Committee. Carried.

Mr. Robert Grimshaw next presented certain views concerning the future policy of the Institute, involving a considerable expansion of

its present operations, and in conclusion offered the following resolutions:

Resolved, That it is the sense of this meeting that the Board of Managers be urged to take such action at their next meeting as will result in the most speedy alteration of the present building to adapt it to the wants of the Institute, and to introduce steam heating and ventilating arrangements in all parts under the supervision of a joint committee composed equally from the Board and the members at large.

Mr. Nystrom suggested that the committee that had been authorized at the last meeting was the proper one to which to refer the resolution just offered.

Mr. Mitchell protested against the tenor of the resolution. He urged that it should be the aim of the Franklin Institute to emulate the usefulness of the many Polytechnic Institutes of Europe; instancing those of London, Paris, Berlin, and especially that of Vienna, as excellent models. He added that it was impossible to place the present building upon such an extensive basis as was demanded by the spirit of the times. He further urged the appropriation of the profits of the late exhibition, and of the money that might be derived from the sale of the present lot and building occupied by the Institute, to the purchase of another site and the erection of another building.

Mr. Wiegand next occupied the floor in defence of the resolution. He claimed that the Institute was not making by any means the best use of the place and room it now possessed; and explained at length, with the aid of projections on the screen, a plan suggested by certain members of the Institute to remodel the present building. The plan in question involved the enlargement of the lecture room to nearly twice its present seating capacity, besides increasing its conveniences for illustrative purposes and lectures, an equivalent enlargement of the present library room and drawing school, the establishment of efficient laboratories, and the steam heating of the whole building. These alterations, he asserted, could be effected at a cost not exceeding $5000.

Mr. Mitchell thought the plan described was altogether inadequate to the wants of the Institute, and moved that the resolution be referred to the committee to be appointed by the President at the next regular meeting.

Messrs. Shaw and Gray opposed such reference, as the result would be simply to bury it, and the purpose of the mover of the resolution was to obtain the sense of the present meeting on the subject.

The question was still further debated by Messrs. Gray, LeVan, Leffmann, Wise, Orr, Bennet, Close, and Branson.

The question upon Mr. Mitchell's amendment to refer to a committee was lost, and the resolution was thereupon carried.

The meeting was then, on motion, adjourned.

WILLIAM H. WAHL, *Secretary.*

HALL OF THE INSTITUTE, December 16th, 1874.

The meeting was called to order at the usual time, with the President, Mr. Coleman Sellers, in the chair.

The minutes of the last meeting were read and adopted, as also those of the special meeting held Monday, Dec. 7th.

The Actuary then submitted the minutes of the Board of Managers, and of the several standing committees. He likewise reported the following extracts from the minutes of the Board, viz.:

"*Resolved*, That a committee be appointed by the Board to prepare and submit plans for the improvement of the present Institute building." Carried.

The President then appointed the following gentlemen, six from the Board and six from the members at large, to serve upon that committee, viz.:

From Board.—Chas. S. Close, J. Vaughan Merrick, Joseph M. Wilson, Robert E. Rogers, E. J. Houston, J. E. Mitchell.

From Institute.—Robert Grimshaw, S. Lloyd Wiegand, J. B. Knight, J. Solis Cohen, Wm. B. Bement, John McClure.

The Actuary, from the minutes of the Board, likewise reported that at their last meeting the following donations to the library had been received:

Annales des Ponts et Chaussées, for July and August, 1874. Paris. From the Editor.

U. S. Coast Survey Report, 1874. Appendix: Tidal Researches, by Wm. Ferrel, A. M. Tidal Discussion of Tides in Boston Harbor,

by Wm. Ferrel. Washington, 1874. From C. P. Patterson, Superintendent.

Report of the Department of Agriculture for 1873. Washington, 1874. From the Commissioner.

Mittheilungen der K. K. Geographischen Gesellschaft in Wien, for 1873. Vienna, 1874. From the Society.

Zeitschrift des Architekten und Ingenieur Vereins zu Hannover. Vol. XX, Part 2. From the Society.

Documents relatif au Congrés International des Sciences Geographiques, qui se réunira á Paris en 1875. Paris, 1875. From the Commissioner.

Circulars of Information of the Bureau of Education. No. 2, 1874. Washington. From the Bureau of Education.

Tilghman's Sand Blast. From Gorham Blake, General Agent for the U. S.

Annual Report upon the Improvement of Rivers and Harbors in New Jersey, Pennsylvania, and Delaware, in charge of J. D. Kurtz, Lieut.-Colonel of Engineers, etc., U. S. A. Washington, 1874. From the author.

Minutes of Proceedings of the Institution of Civil Engineers, with abstracts of the Discussions. Vols. 37-38. London. From the Society.

Report of the Chief Signal Officer, War Dept. 1872-73. From the signal officer at Philadelphia.

Report of the Commissioner of Fish and Fisheries, Part 2, for 1872-73. Washington. From the Commissioner.

The report of the Secretary on novelties in science and the mechanic arts next followed; upon which the President gave an account of a recent discovery of mica in considerable quantities and of good quality on the coast of Labrador.

Nominations for officers of the Institute were then declared in order, and the President announced that, in accordance with the By-Laws, there were to be chosen at the stated meeting next following, a President, Secretary, Treasurer, and Auditor, to serve for one year, a Vice-President and eight Managers to serve for three years, and, in consequence of the resignation of Mr. F. B. Miles from the Board, before the expiration of his term of office, one Manager to serve for two years.

The following members were then put in nomination:

For President, Coleman Sellers (declined), Bloomfield H. Moore, Dr. Robert E. Rogers.

For Vice-President, J. E. Mitchell, Coleman Sellers, Charles S. Close, Wm. P. Tatham.

For Secretary, William H. Wahl (declined), J. B. Knight, Robert Grimshaw.

For Treasurer, Fred'k Fraley.

For Managers for three years, Theo. D. Rand, Thos. Shaw (declined), Thos. J. Lovegrove, Sterling Bonsall, Washington Jones, G. Morgan Eldridge, Jas. M. Wilson, Coleman Sellers, William H. Wahl, Pliny E. Chase, Th. Norris, Jr. (declined), Chas. S. Close, Wm. P. Tatham, Stephen P. M. Tasker (declined), Geo. F. Barker, Cyrus Chambers, Jr., Chas. H. Cramp, J. Sellers Bancroft, John H. Cooper (declined), Chas. H. Heller, Chas. M. Cresson, Wm. B. Bement, Sam. S. Hart (declined), Isaac Norris, Jr.

For Manager for two years, Samuel Hart, Alex. Purves, Geo. V. Cresson, and

For Auditor, James H. Cresson.

The President then announced the appointment of the following members to serve as Judges of the Election, namely:

William A. Rolin, Geo. Gordon, M. W. Haines, John Hoskin, William Biddle, Samuel Sartain, and William Taggart.

The Secretary then read by request a paper presented by Mr. Thomas Shaw, alleging a number of grievances suffered by various exhibitors who participated in the late exhibition, and charging upon the Board of Managers certain irregularities—notably in their not complying with their printed rules and regulations, and in overstepping their authorities. On the conclusion of the reading Mr. Shaw offered the following preamble and resolution, viz.:

WHEREAS, The action of the Board of Managers in making awards of premiums on articles competing at late exhibition has caused a great deal of dissatisfaction on the part of exhibitors, who complain that the Board has not complied with the rules and regulations under which they invited competition; therefore,

Resolved, That a Committee of Appeal, consisting of seven members be nominated by this meeting from among those not managers, which committee shall have power to examine any case which may be

brought before them on appeal and decide whether the award of premium as made by the Board, is in accordance with the rules and regulations adopted and published by said Board, and if they may find said rules have not been complied with, then to modify said award in accordance with said rules and the requirements of justice.

The resolution was seconded by Mr. Gray.

Mr. J. B. Burleigh moved to amend by referring the subject to the Committee on Science and the Arts.

The amendment was discussed pro and con by Messrs. Burleigh, Shaw, and others.

Mr. Henry Cartwright stated that the mover of the resolution was probably not correctly informed as to the official action of the Board upon the awards, and that any misunderstanding could be obviated if the President would state what had been done concerning the adjustment of disputed cases.

The President then stated that he, as well as other officers of the Institute, had been the recipient of a number of complaining letters, and that these had invariably been referred to the Judges; that the Judges of many of the classes had met and reviewed their work in the light of the objections raised, and that they had in a number of instances modified their reports; that, furthermore, these modified reports would be brought up before the Board again on the Monday following. The President then read the form of circular that had been addressed to the Judges for this purpose.

Mr. Sterling Bonsall and Mr. Gray then successively occupied the floor, claiming that the Managers had overstepped their authority in presuming to revise and amend the reports of the Judges; claiming from the statements of the printed rules and regulations, that the choice of the awards of merit was vested in the Judges, and that their decision should be final.

Messrs. Lovegrove and Burleigh then occupied the floor in favor of the amendment to refer to the Committee on Science and the Arts.

Mr. Chas. S. Close remarked that any action upon the resolution or the amendment at this time would be premature, in view of the fact that as yet the report of the Board of Managers had not been officially made public. He therefore moved the postponement of action upon the same until the next monthly meeting.

In connection with the same subject, Mr. Gravenstine called atten-

tion to a communication which he had addressed to the Institute, and was now in possession of the Secretary.

The President decided that the whole subject had been postponed by the resolution just passed.

The President then announced the following committee to consider the subject of the selection of a new site and the erection of a new building for the Institute, which committee had been ordered at the stated meeting previous to this, viz.: Messrs. J. W. Nystrom, chairman; William Sellers, J. Vaughan Merrick, Enoch Lewis, and Henry G. Morris.

The meeting thereupon adjourned.

WILLIAM H. WAHL, *Secretary.*

SPECIAL MEETING.

HALL OF THE INSTITUTE, December 23d, 1874.

The meeting was called to order at the usual hour, with Vice-President, Dr. Robt. E. Rogers, in the chair.

The Secretary read the following call, in obedience to which the President had authorized the meeting, viz:

Hall of the Franklin Institute, Dec. 18th, 1874.

Coleman Sellers, Ex-Pres't.,—Dear Sir:—The undersigned members of the Franklin Institute, respectfully request that a Special Meeting be called for Wednesday Evening, 23d inst., to consider some proposed changes in the By-Laws, to be discussed at the next stated meeting.

(Signed by twelve members and authorized by the President.)

The President *pro tem.*, declared the meeting ready to transact its business.

Mr. Gray then called for the reading of the minutes of the last meeting of the Board of Managers.

The President *pro tem.* decided that the call for the minutes of the Board is only in order at the stated meetings of the Institute.

Mr. Wiegand then read from the By-Laws, Section XV, that the Board shall keep regular minutes of their proceedings, which shall be open at all times to the inspection of members.

Mr. Close remarked that the minutes were at all times open for inspection, but that the present meeting was only interested in the objects specified in the call.

Several members then followed with an inquiry as to the object of the meeting.

Mr. Robert Grimshaw in reply offered the following resolution, which was duly seconded by Mr. George Gordon, viz.:

Resolved, "That a committee of two from the Board of Managers, and five from the members at large be appointed, and instructed to report an amendment to the By-Laws, clearly defining the powers of the Board of Managers."

The reading of the By-Laws on the subject was called for.

Messrs. Close, Grimshaw, Tatham, Purves, and Gray debated the question as to the legality of offering amendments to the By-Laws at a special meeting.

Mr. Wiegand remarked his position as a signer of the call, and defined it to be a meeting to propose and discuss alterations and not to offer or effect them. Amongst other needed modifications, he mentioned as most important, a clear definition of the limits of the Board, and the reorganization of the Committee on Science and the Arts, by undoing the establishment of sections.

Mr. Robert Briggs followed by reading from the By-Laws the section defining the powers of the Board, and presented his views thereon. He wished to inquire what grounds there were for desiring a disturbance of the existing relations.

Mr. Grimshaw, in reply, specified a number of cases in which, in his opinion, the Board had transcended the powers vested in it by the By-Laws, and stated that the object of his resolution was to define clearly, by negative limitations, the powers of that body; but added that since there seemed to be some doubt as to whether he was strictly in order, he would withdraw the resolution.

Some further discussion followed without definite action, upon which the meeting was adjourned.

WILLIAM H. WAHL, *Secretary.*

Civil and Mechanical Engineering.

REMARKS ON THE EXPERIMENTS MADE WITH A SMALL NON-CONDENSING STEAM-ENGINE BY B. DONKIN & CO., LONDON, SHOWING THE RELATIVE ECONOMIC EFFICIENCY OF STEAM-JACKETING, AND OF USING STEAM WITH DIFFERENT MEASURES OF EXPANSION.

By Chief Engineer B. F. Isherwood, U. S. Navy.

The issue of *Engineering* dated October 16th, 1874, contains an article headed "Steam Jackets," in which are given the particulars of the experiments made at the factory of B. Donkin & Co., London, on a small non-condensing beam engine, with a view to ascertain the economy derived from the addition of a steam-jacket to the cylinder. The data appear to me sufficient for the determination of several important facts besides the economy of the steam-jacket; and, in the belief that conclusions wider, different, and more numerous than those drawn by the writer of the article are properly deducible from the observed quantities, I have made the necessary calculations from them in my own way, as given in the accompanying Table, and have inferred from them what seems to me the correct and complete results. Before proceeding to a discussion of these results, I will quote from the article referred to the following description of the experimental engine, and of the manner of experimenting:

"The engine on which the experiment was carried out was one of "a pair of compound beam engines built in 1838, and which, at one "time, drove Messrs. Donkin's works. Having long been supplanted "in this work by a larger engine, Messrs. Donkin have retained the "old engines in their place for experimental purposes, and have modi- "fied them in various ways, to enable trials to be carried out under "different conditions. In the case of the experiments of which we "are about to speak, the low-pressure piston, etc., of one engine was "disconnected and the high-pressure cylinder was fitted with suitable "double slide valves, so that the engine could be driven as an ordi- "nary non-condensing engine, at different degrees of expansion. The "cylinder is $7\frac{5}{16}$ inches in diameter, and 2 feet $2\frac{1}{8}$ inches stroke,

"and is steam-jacketed, the cylinder being let into the jacket, and "the joint made with iron cement. The steam casing was proved to "be perfectly steam-tight, and the cylinder and piston were in good "order and free from leakage when the experiments were made. "The steam passages are cast on the cylinder, and the slide is near "the top, so that the passage leading to the bottom of the cylinder is "very long. Thus the capacity of the top passage is 60 cubic inches, "and the clearance space above the piston 21 cubic inches, making a "total clearance at the top of 81 cubic inches; while at the bottom "the capacity of the passage is 155 cubic inches, and the clearance "below the piston 34 cubic inches, making a total clearance space at "the bottom of 189 cubic inches. The top clearance spaces thus "amount to 7·4 and the bottom clearance spaces to no less than 17·2 "per centum of the volume swept through by the piston, the mean "clearance being thus 12·3 per centum.

"As we have said, the engine on which the experiments were made "is one of a pair, and advantage was taken of this fact to obtain a "constant resistance in the following way: The slide valve of the fel- "low engine was taken out and that engine was made to draw air "into its cylinders and force it out again through two pipes, the ends "of which were furnished with cocks, so that the resistance to both "in-going and out-coming air could be regulated at pleasure. Self- "acting lubricators were fitted to both cylinders, and in this way it "was rendered possible to obtain a constant resistance; in fact the "power thus absorbed was so nearly absolutely constant that a dif- "ference of but 3 per centum existed between the maximum and "minimum indicator cards in any given experiment. The revolutions "made by the engine were registered by a counter, and the indicator "diagrams were taken by a pair of Richards' indicators driven from "the parallel motion direct, and the springs of which had been care- "fully tested before being used.

"The amount of water used in each experiment was carefully ascer- "tained by weighing it, special provisions being made to secure accu- "racy. As the steam-jacket extended round the large cylinder (the "piston of which was, as we have said, disconnected), and as there "was a considerable length of 2 inches steam pipe between the engine "and the boiler, it was desirable to ascertain what quantity of steam "was condensed in the pipe and jacket when the engine was still. "This was accordingly tried for five hours at a time on two occasions,

"and the quantity condensed was found to be 30 pounds per hour in "each case."

The area of the piston-rod of the steam-cylinder is not given, but I have assumed it at the usual proportion, and having deducted it, find the net area of the steam-piston to be 41·6 square inches. The stroke of that piston being 2·1771 feet, its space displacement per double-stroke or per revolution of the crank, is 1·25787 cubic feet, to which adding the spaces at the top and bottom of the cylinder in clearances and steam passages, namely, 0.17625 cubic foot, we have for the bulk of steam exhausted from the cylinder per double-stroke of piston, 1·41412 cubic feet. The calculations in the following Table have been made for the above quantities.

The principal objection to these experiments as regards accuracy, is the shortness of their duration; the time in two of them being only two hours and 45 minutes, in two others, three hours; and in the remaining two, four hours and 30 minutes. It is very difficult to leave the water-level in a boiler at the end of an experiment just where it was at the beginning, and with the water at the same temperature and having the same pressure upon it; yet the accuracy of the results depends on such equality, for the quantity of water pumped into the boiler is the measure of the cost of the various effects produced, and if the area of the water-surface in the boiler be proportionally large, much error may occur from this source, and, being absolute, will be relatively so much the greater as the duration of the experiment is so much the shorter.

The number of indicator-diagrams taken in the different experiments, and from which the steam pressures in the cylinder are ascertained, was 38 in each of the experiments in columns A and B of the following Table, 22 in each of the experiments in columns C and D, 26 in the experiment in column E, and 24 in the experiment in column F. On their correctness depends the correctness of the powers computed from them. As regards these diagrams, data is wanting in three important particulars, namely, the back pressure against the piston, the pressure required to work the engine, *per se*, or unloaded, and the height of the barometer. I have supplied, in all three cases, the omission from my own experience with similar engines, assuming the back pressure to be 1·3 pounds per square inch of piston above the atmosphere or 16 pounds per square inch above zero; the pressure

required to work the unloaded engine or to overcome its friction, *per se*, 2 pounds per square inch of piston; and the height of the barometer at 29·92 inches of mercury.

EXPLANATION OF THE FOLLOWING TABLE CONTAINING THE DATA AND RESULTS OF THE EXPERIMENTS.

The data and results of the experiments will be found in the following table, in columns lettered from A to F, both inclusive. The quantities, for facility of reference, have been grouped and the lines containing them numbered.

Line 1, gives the duration of the experiments in hours and minutes.

ENGINE.—Line 2, contains the steam-pressure in the boiler. This pressure was constant in all the experiments at 45 pounds per square inch above the atmosphere.

Line 3, contains the mean number of double strokes of piston, or revolutions of crank, made per minute during the experiment, as given by a self registering counter.

Line 4, contains the number of pounds of feed-water pumped into the boiler per hour.

Line 5, contains the number of pounds of steam condensed per hour in the steam-pipe and steam jacket by external radiation alone; the temperature of the steam being that (292¼ degrees Fahrenheit) normal to its boiler pressure of 45 pounds per square inch above the atmosphere, or 59·7 pounds per square inch above zero; and the temperature of the air surrounding the steam-pipe and steam-jacket being that given on line 9.

Line 6, contains the number of pounds of water of condensation drawn from the steam-jacket of the cylinder per hour, and is inclusive of the quantity on line 5 in the experiments (columns A, C and E), in which steam was used in the jacket.

Line 7, gives the per centum which the quantity on line 6 is of the quantity on line 4.

Lines 8 and 9, contain the mean temperatures in degrees Fahrenheit of the external atmosphere and of the engine-room during the experiments.

STEAM-PRESSURES IN CYLINDER PER INDICATOR.—The quantities on lines 10 to 15, both inclusive, are the means of the indicator-diagrams with the exception of the quantity on line 12 for which the back-pressure against the piston was assumed at 1·3 pounds per square

inch above the atmosphere, and the atmospheric pressure was assumed at 14·7 pounds per square inch above zero, making a total of 16 pounds per square inch of piston above zero. The quantity on line 14 is the sum of those on lines 12 and 13, and the quantity on line 15 is the remainder of that on line 13 after deducting 2 pounds per square inch of piston for the pressure required to work the unloaded engine. The quantities on lines 10 and 11 are the pressures given in the original data in pounds per square inch of piston above the atmosphere, plus the assumed atmospheric pressure of 14·7 pounds per square inch.

POWER—*Absolute.*—Line 16, contains the gross effective indicated horse-powers developed by the engine, that is to say, the power corresponding to the area of the indicator diagram. It is computed from the speed of piston on line 3 and the pressure on line 13; and represents the work done by the steam in overcoming the external load and its friction, and the friction of the engine, *per se*; but is exclusive of the work done in overcoming the back-pressure.

Line 17, contains the total horse-powers developed by the engine computed from the speed of piston on line 3 and the pressure on line 14. This power represents the whole work done by the steam, both in overcoming the back-pressure, the frictions of the external load and of the engine *per se*, and in moving the external load.

Line 18, contains the net horse-powers developed by the engine, calculated from the speed of piston on line 3, and the pressure on line 15. This power represents the external work done by the steam, and in overcoming the friction of that work; but is exclusive of the work done in overcoming the back-pressure and the friction of the engine, *per se*.

POWER—*Economic.*—Lines 19, 20 and 21, contain respectively the cost of the gross-effective, total, and net horse-power in pounds of feed-water (or pounds of steam) consumed per hour. These quantities are the quotients of the division of the quantity on line 4 by those on lines 16, 17 and 18.

CONDENSATION.—Line 22, contains the number of pounds of steam discharged per hour into the atmosphere from the cylinder, calculated from the pressure of the steam at the end of the stroke of the piston, line 11. This is not necessarily the whole quantity of steam discharged into the atmosphere from the cylinder; for should there be

any water of condensation in the cylinder when the exhaust port is opened at the end of the stroke of the piston, it will be vaporized and pass into the atmosphere during the exhaust stroke under the lessened pressure and by its contained heat and the heat in the metal of the cylinder.

Line 23, contains the number of pounds of steam condensed per hour in the boiler and cylinder to furnish the heat transmuted into the total power developed by the engine. It is calculated for the thermal equivalent of one pound of water at 32 degrees Fahrenheit raised one degree Fahrenheit in temperature for every 772 foot-pounds of work done by the engine.

Line 24, contains the sum of the quantities on lines 22 and 23, and it is all of the steam evaporated in the boiler (line 4) which can be accounted for by means of the indicator. Of course, none of the steam condensed by external radiation from the steam-pipe and cylinder surfaces, or within the cylinder by any cause other than the production of the power, is, or can be, included. The quantity on line 24 will always be less than that on line 4, unless superheated steam raised to a sufficiently high temperature to prevent condensation, be employed.

Line 25, contains the per centum which the difference of the quantities on lines 4 and 24 is of the quantity on line 4, and shows the per centum of the weight of steam evaporated in the boiler which is condensed by external radiation from the steam-pipe and cylinder surfaces, and within the cylinder by any cause other than the production of the power.

The sum of the quantities on lines 24 and 6 being subtracted from the quantity on line 4, the remainder, expressed in per centum of the quantity on line 4, is given on line 26. The quantity on line 26, therefore, is only for experiments A, C and E, in which steam was used in the jacket, and shows, in per centum of the weight of steam evaporated in the boiler, the weight of steam condensed within the cylinder by causes other than the production of the power.

The sum of the quantities on lines 24 and 5 being subtracted from the quantity on line 4, the remainder, expressed in per centum of the quantity on line 4, is given on line 27. The quantity on line 27, therefore, is only for experiments B, D and F, in which steam was not used in the jacket, and shows, in per centum of the weight of steam evaporated in the boiler, the weight of steam condensed within the cylinder by causes other than the production of the power.

TABLE CONTAINING THE DATA AND RESULTS OF THE EXPERIMENTS MADE ON A STEAM-JACKETED NON-CONDENSING STEAM-ENGINE AT THE FACTORY OF B. DONKIN & CO., LONDON, USING STEAM OF THE SAME BOILER PRESSURE WITH AND WITHOUT STEAM IN THE JACKET, WITH AND WITHOUT THROTTLING, AND WITH DIFFERENT MEASURES OF EXPANSION.

No. of Line.			Steam cut off at ⅘ of the stroke of the piston, and not throttled.		Steam cut off at ⅓ of the stroke of the piston, and not throttled.		Steam cut off at ⅕ of the stroke of the piston, and much throttled.	
			Steam in Jacket.	No ste'm in Jacket.	Steam in Jacket.	No ste'm in Jacket.	Steam in Jacket.	No ste'm in Jacket.
			A	B	C	D	E	F
1		Duration of the experiment in hours and minutes	4·30	4·30	2·45	2·45	3·00	3·00
2	Engine.	Steam pressure in boiler, in pounds per square inch above the atmosphere	45·	45·	45·	45·	45·	45·
3		Number of double strokes of engine's piston made per minute	48·31	44·81	51·17	46·82	45·63	47·00
4		Pounds of feed-water pumped into the boiler per hour	361·244	354·155	562·145	556·364	334·667	419·667
5		Pounds of steam condensed per hour in the steam pipe and steam-jacket, by external radiation	30·000	.....	30·000	.....	30·000	.....
6		Pounds of water of condensation drawn from the steam-jacket of the cylinder per hour	53·333	.....	47·636	.....	47·000	.....
7		Per centum of the feed-water pumped into the boiler drawn from the steam-jacket as water of condensation	14·76	.....	8·47	.....	14·04	.....
8		Temperature, in degrees Fahrenheit, of the external atmosphere	43·	35·5	33·	32·	37·	35·5
9		Temperature, in degrees Fahrenheit, of the engine-room	62·	62·5	74·75	61·	73·5	63·00
10	Steam Pressure in Cylinder per Indicator.	In pounds per square inch above zero, at commencement of stroke of piston	56·70	53·70	59·20	55·70	39·70	41·70
11		In pounds per square inch above zero, at end of stroke of piston	22·70	21·20	41·70	40·20	25·20	28·70
12		In pounds per square inch above zero, against the piston during its stroke	16·00	16·00	16·00	16·00	16·00	16·00
13		Mean gross-effective pressure on piston, in pounds per square inch	23·97	19·93	37·31	34·30	17·89	19·35
14		Mean total pressure on piston, in pounds per square inch	39·97	35·93	51·31	50·30	33·89	35·35
15		Mean net pressure on piston in pounds per square inch	22·47	18·43	35·81	32·80	16·39	17·85
16	Economic Absolute Power.	Gross-effective horse-powers developed by the engine	6·356	4·902	10·479	8·815	4·481	4·992
17		Total horse-powers developed by the engine	10·599	8·837	14·411	12·927	8·488	9·120
18		Net horse-powers developed by the engine	5·958	4·533	10·058	8·430	4·105	4·605
19		Pounds of feed-water pumped into the boiler per hour per gross-effective horse-power	56·835	72·247	53·645	63·116	74·686	84·068
20		Pounds of feed-water pumped into the boiler per hour per total horse-power	34·083	40·076	39·008	43·039	39·428	46·016
21		Pounds of feed-water pumped into the boiler per hour per net horse-power	60·632	78·128	55·890	65·998	81·527	91·133
22	Condensation.	Pounds of steam discharged per hour from the cylinder, calculated from the pressure of the steam at the end of the stroke of the piston	236·808	205·678	448·781	396·584	247·294	288·547
23		Pounds of steam condensed per hour in boiler and cylinder, to furnish the heat transmuted into the total power	29·924	24·950	40·687	36·497	23·964	25·749
24		Sum of the above two quantities; or weight of steam per hour accounted for by the Indicator,	266·732	230·628	489·468	433·081	271·258	314·296
25		Per centum of the steam evaporated in the boiler not accounted for by the Indicator	26·16	34·88	12·93	22·16	18·95	25·18
26		Per centum of the steam evaporated in the boiler not accounted for by the Indicator & st'm-jacket	11·40	.....	4·45	.....	4·90	.....
27		Per centum of the steam evaporated in the boiler not accounted for by the Indicator and external radiation	.....	26·41	.....	16·77	.....	19·76

Discussion of the Results.

The experiments determine for the experimental conditions:

1st. The relative economic efficiency under various initial, mean total, and back-pressures in the cylinder, of the two measures of expansion used, namely, those due to cutting off the steam at $\frac{3}{8}$ and at $\frac{2}{3}$ of the stroke of the piston from the commencement, and they determine it for the two cases of with and without steam in the jacket.

2d. The relative economic efficiency of the steam-jacket for various initial, mean total, and back-pressures, in the cylinder; and for the two measures of expansion with which the steam is used.

3d. The quantity of steam condensed in the jacket to furnish the heat imparted to the cylinder, and acting for the prevention of the condensation of steam in the cylinder. This quantity of steam thus condensed in the jacket is exclusive of the quantity therein condensed by external radiation.

4th. The quantity of steam condensed in the cylinder by causes other than those due to external radiation and to the production of the power.

Of the Relative Economic Efficiency of the Two Measures of Expansion due to Cutting off the Steam at three-eighths and at two-thirds of the Stroke of the Piston.

The relative economic efficiency obtained from cutting off the steam at $\frac{3}{8}$ and at $\frac{2}{3}$ of the stroke of the piston from the commencement, varies greatly according to the conditions of the cylinder pressures. For a correct engineering comparison, the cost in pounds weight of steam consumed per hour to produce the total horse-power developed by the engine should be employed; because that power includes all the resistances of what kind soever overcome by the steam admitted to the cylinder. This comparison by total horse-power supposes either no back-pressure against the piston, or that the back-pressure with the two measures of expansion employed is the same per centum of the total pressure, which corresponds to the case of equal net powers developed in the same cylinder with equal speed of piston but with unequal initial pressure, the initial pressure being carried as much higher with the shorter cut-off as is necessary to make the net pressure on the piston equal.

Taking then the case of column A in the Table, in which the steam was cut off at $\frac{3}{8}$ of the stroke of the piston, with the boiler steam present

in the jacket, we have the cost of the total horse-power 34·083 pounds of feed-water per hour (line 20 of the Table); while in the cases of columns C and E, in which the steam was cut off at $\frac{3}{8}$ of the stroke of the piston, with the boiler steam also present in the jacket, we have the cost of the total horse-power 39·008 and 39·428 pounds of feed-water per hour, the mean of which is 39·218 pounds; consequently, the economic efficiency when cutting off at $\frac{3}{8}$ of the stroke of the piston was $\frac{39{\cdot}218 - 34{\cdot}083 \times 100}{39{\cdot}218} = 13{\cdot}09$ per centum greater than when cutting off at $\frac{3}{8}$ of the stroke of the piston, assuming the cost for the latter as unity.

If, however, the comparison be made for the cost of the net horse-power instead of for the total horse-power, in pounds of feed-water consumed per hour, a very different result will be obtained. Now, the net horse-power is that portion of the total horse-power developed by an engine which is commercially valuable, that is to say, the portion which moves the external load; and the results of the comparison with it, determines the practical value of the different points of cut-off. Taking, then, the case of column A, as before, cutting off at $\frac{3}{8}$ of the stroke of the piston with the boiler steam in the jacket, we have 60·632 pounds of feed-water consumed per hour per net horse-power (line 21); while in the case of column C, with the boiler steam in the jacket, but cutting off at $\frac{3}{8}$ of the stroke of the piston, we have only 55·890 pounds of feed-water consumed per hour for the cost of the net horse-power, so that the previous economy in favor of the $\frac{3}{8}$ cut-off is actually reversed, becoming $\frac{60{\cdot}632 - 55{\cdot}890 \times 100}{55{\cdot}890} = 8{\cdot}48$ per centum in favor of the $\frac{3}{8}$ cut-off, assuming the cost with the latter at unity as before. Nevertheless, if, instead of making this comparison for the case of column C, we make it for the case of column E, in which the same boiler-steam is used in the jacket, and the same point of cutting off is employed in the cylinder, but in which the relation of the back-pressure to the total pressure is very different, we obtain a very different result, the cost of the net horse-power rising to 81·527 pounds of feed-water per hour, and the economic efficiency when cutting off at $\frac{3}{8}$ of the stroke of the piston, becoming $\frac{81{\cdot}527 - 60{\cdot}632 \times 100}{81{\cdot}527} =$ 25·63 per centum greater than when cutting off at $\frac{3}{8}$ of the stroke of

the piston. In the case of column A, the back-pressure (line 12) against the piston was 40·03 per centum of the total pressure (line 14), while in the case of column C it was 31·18 per centum, and in the case of column E 47·21 per centum. A slight consideration will show how completely this relation of the back-pressure to the sum of the friction and total pressures, and not the Mariotte law, governs the economy in the practical steam-engine of different measures of expansion. The shorter the cut-off, with a given initial pressure, the smaller is the mean total pressure; and the longer the cut-off, the larger is the mean total pressure; and we can easily suppose the cut-off so short that the mean total pressure will be but a little above the sum of the friction and back-pressures, most of the steam used being in this case expended in overcoming resistances of no commercial value; while with a long cut-off with its large mean total pressure so much less a portion of the steam will be expended in overcoming the non-commercial resistances, that the less measure of expansion will give actually greater economic results than the large measure of expansion, as is practically illustrated in these experiments, the sum of the back-pressure and friction-pressure of the engine, *per se*, being constant. Thus it is seen that, the practical economy for the net or commercial horse-power, due to different measures of expansion, depends mainly on the relation between the mean total pressure upon the piston, and the sum of the back-pressure and friction of the engine, *per se:* and that this economy is not at all inferable from the Mariotte law, but is a practical result to be obtained from practice alone, and will vary with every variation in the practical conditions.

In the case of our experimental engine the waste spaces in the clearances and steam-passages at the ends of the cylinder were about double of the average in practice, and this excess operated against the shorter cut-off. With each reduction of these spaces, the shorter cut-off becomes relatively more economical, but in a subordinate degree, the great cause of the discrepancy being the different proportions of the mean total pressure to the sum of the friction and back-pressures. It must be remarked here, too, that under the experimental condition of the same boiler-pressure in the jacket, that condition operates more favorably for the shorter than for the longer cut-off, by the greater difference between the temperature in the jacket and in the cylinder, due to the less mean total pressure with

the shorter cut-off: but, under the actual experimental conditions, the difference in the temperature of the mean total pressure in the different experiments was not sufficiently great to produce any practical difference in the economic result.

The preceding discussion was for the condition of steam in the jacket, but experiments B, D and F, allow the comparison of the relative economic efficiency of using steam with the measures of expansion due to cutting off at $\frac{1}{8}$ and at $\frac{3}{8}$ of the stroke of the piston to be ascertained for the condition of no steam in the jacket. Here, too, the comparison should be made for the cases of equal mean total pressure and of different mean total pressure. For the former case, we can compare the cost of the total horse-power in pounds of feed-water consumed per hour in column B, with that in column F, the mean total pressure (line 14) being almost exactly the same in both.

In column B, cutting off at $\frac{1}{8}$ of the stroke of the piston, the total horse-power cost 40·076 pounds of feed-water per hour, while in column F it cost 46·016 pounds, showing an economy of $\frac{46{\cdot}016 - 40{\cdot}076 \times 100}{46{\cdot}016} = 12{\cdot}91$ per centum for the shorter cut-off, or almost exactly the same as when steam was used in the jacket. But in the case of column D in which the mean total pressure was much higher than in column B, the total horse-power cost only 43·039 pounds of feed-water per hour, making the economy when cutting off at $\frac{1}{8}$ of the stroke of the piston only $\frac{43{\cdot}039 - 40{\cdot}076 \times 100}{43{\cdot}039} = 6{\cdot}88$ per centum greater than when cutting off at $\frac{3}{8}$ of the stroke of the piston. Thus, it appears that the relative economic efficiency of different measures of expansion in the case when steam is not used in the jacket, depends, even for the total horse-power, on the absolute mean total pressure in the cylinder, the greater this pressure the more the economy; another very important practical modification for the abstract Mariotte law.

As, under the condition of steam in the jacket, so, under the condition of no steam in the jacket, the relative economic efficiency of the two measures of expansion is easily reversed by difference in the ratio of the mean total pressure to the sum of the friction and back-pressures; for example: comparing, for columns B and D, the cost of the net horse-power in pounds of feed-water consumed per hour, we

have for column B, cutting off at $\frac{1}{4}$ of the stroke of the piston, 78·128 pounds; and for column D, cutting off at $\frac{1}{4}$ of the stroke of the piston, 65·998 pounds; or $\frac{78{\cdot}128-65{\cdot}998\times 100}{65{\cdot}998}=15{\cdot}52$ per centum greater economy for the long cut-off instead of 12·91 per centum against it, as in the comparison for the total horse-power; while for column F, cutting off also at $\frac{1}{4}$ of the stroke of the piston, the cost of the net horse-power rises to 91·133 pounds of feed-water per hour, showing an economy for the shorter cut-off of $\frac{91{\cdot}133-78{\cdot}128\times 100}{91{\cdot}133}=$ 14·27 per centum. Thus, the economic result, when no steam is used in the jacket, depends not only on the measure of expansion, and on the absolute mean total pressure, but also on the ratio of the mean total pressure to the sum of the friction and back-pressures.

The results of these experiments fully confirm the results of those made by the writer on the economy of using steam with different measures of expansion, vindicating the accuracy of his perceptions and the truth of his deductions.

(To be continued.)

ON THE METHODS OF TESTING STEAM ENGINES;

With a Description of the Trials of the Circulating Pumps on the U. S. S. "Tennessee."

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and
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[Continued from Vol. lxviii, page 396.]

Independent circulating pumps for marine engines are rapidly gaining favor; being independent of the main engines they can be run at any desirable speed, and as they are generally in duplicate, one can be repaired if necessary, while the other is doing duty.

In addition, they furnish a great safeguard against foundering at sea in case of accident to the main engines. If the pumps were attached to the main engines, the same weight of water could be delivered overboard if the engines could be run at the proper speed, but it must be remembered that it takes the whole power of the boilers to run the engines at the ordinary speed, and that their speed cannot be increased in an emergency, but oftentimes by reducing the speed of

the main engines, the independent circulating pumps can be kept at their maximum; hence their great advantage.

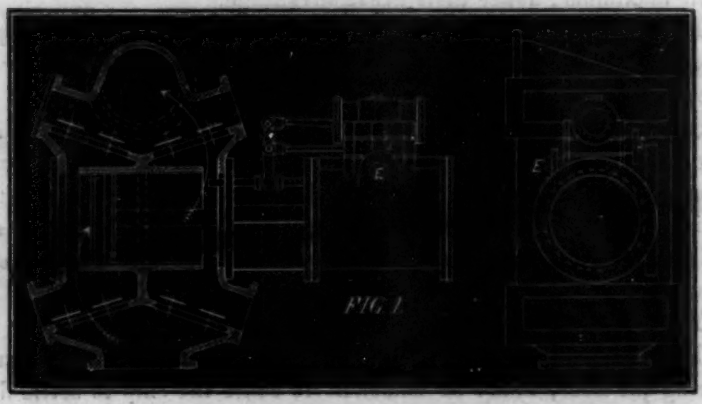
It is not often considered the immense weight of water that the circulating pumps are continually passing through the condenser and overboard. By reference to the experiments it will be seen that at a speed of 97 strokes per minute they were together capable of delivering nearly 1000 tons per hour. In case of an emergency they could be run at 150 strokes per minute, and delivering 1500 tons per hour. This water, which is ordinarily drawn from the sea, may be, by suitable arrangement of pipes, drawn from the bilge and pumped overboard.

The displacement of the "Tennessee" is about 300 tons per foot at load draft. Thus, the 1500 tons of water, if allowed to accumulate during the hour, would be sufficient to cause the ship to settle down in the water 5 feet, supposing she should settle on an even keel, but, if as is usually the case when vessels are foundering, she should commence to settle by the head or stern, probably much less than 1500 tons would be sufficient to sink her.

The following are the dimensions of the Circulating Pumps:

Diameter of steam cylinder,	18 in.
" water "	18 in.
" piston rod,	$2\frac{1}{8}$ in.
Length and breadth of steam port,	5 in. by $1\frac{1}{4}$ in.
" " exhaust port,	5 in. by $2\frac{1}{2}$ in.
Stroke of piston (maximum),	$19\frac{3}{4}$ in.
" " "actual,"	$18\frac{1}{4}$ in.
Width of opening of steam valve,	$\frac{3}{8}$ in.
" " exhaust "	$\frac{3}{8}$ in.
Diameter of auxiliary piston,	5 in.
Stroke " "	$\frac{3}{4}$ in.
No. and diameter of receiving valve,	6–7 in.
No. and diameter of delivery valve.	6–7 in.
Total area of valve openings (6 valves),	171 sq. in.
Ratio of piston area,	$\frac{2}{3}$
Diameter of receiving and discharge nozzles,	15 in.
Distance of centre of pump below water line,	2 ft. 6 in.
Greatest length of pump,	7 ft.
" width of pump,	2 ft. 10 in.
" height of pump,	5 ft.

Fig. 1 shows a section and elevation of the pump.

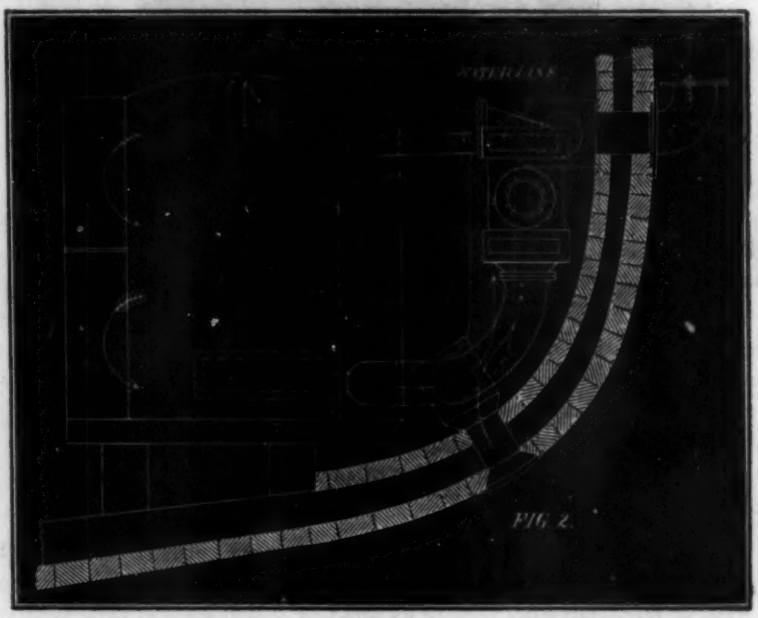


There are two of these pumps used for circulating the water through the condenser. Each pump has a separate suction pipe, drawing water through a strainer containing 2000 ½-inch holes, in the bilge of the ship, thence to a Kingston valve, and through 15 feet of 15-in. copper pipe, to pumps, and delivering through 13 feet of 15-inch copper pipe to top of condenser. Here the water from both pumps combines and passes four times through nests of condenser tubes, each nest containing 1978 tubes, ½ inch internal diameter and 7 feet 3½ inches long, and thence through two copper pipes, each 15 inches diameter and 25 feet long, to outboard delivery valves, 24 inches below the surface of the water outside. For the purpose of this experiment a 15-inch copper pipe was bolted to each outboard delivery valve, to carry the water up to a tank, where it could be measured. This pipe had at the lower end a right angle bend of a central radius equal 14 inches, and at the upper end a return bend or goose-neck of the same radius.

The height of the centre of the goose-neck above the surface of the water was 11 feet. An additional length of leather pipe, 4 feet long, was fastened to the goose-neck, in order to carry the stream below the surface of the water in the tank, as it was found that if the stream fell through the air into the tank, so much air would be carried down with it as to render it impossible to know how high the surface of the water in the tank was. When the stream was protected the surface was clear and smooth. It was proposed to measure the water by allowing it to flow through a number of orifices in the bottom of the

tank, each orifice being small enough to allow the water delivered by it to be measured separately at any instant during the experiment; the sum of all the deliveries, or the average of a sufficient number to determine a mean multiplied by the number of orifices, being the amount of water discharged.

Fig. 2 shows a section through the condenser and side of the ship; the arrows showing the course of the water.



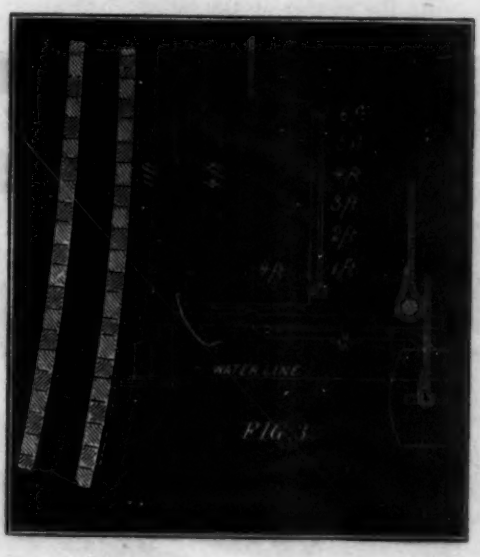
There was a separate tank for each outboard delivery, of the following dimensions: diameter, 48 inches; height, 72 inches; thickness, $\frac{1}{4}$ inch.

A hole, 24 inches in diameter, was cut in the bottom, and a composition plate, planed 1 inch thick and 28 inches diameter, was bolted upon the under side. There were drilled in this plate 55 holes, each hole being $1\frac{1}{8}$ inches diameter, and beveled out on the upper side, the depth of the bevel being $\frac{1}{4}$ inch and the angle 30° from the vertical side of the hole. The average distance between the centre of these holes was $3\frac{1}{4}$ inches.

During the experiment a portion of the holes was plugged up with soft pine plugs. During the experiment the pump worked under the

additional load due to the 11 feet head on the standing pipe and the friction of the sides and bends—more than would be required when in regular use at sea.

Fig. 3 shows the arrangement of the tank in reference to the water and side of the ship, and the method of supporting the platform and measuring barrel.



It will be seen that the two circulating pumps act entirely as meters of the best construction, for they are sufficiently far below the surface of the water outside the ship to be filled to overflowing at every stroke, and the entire cylinder full of water must be forced through the condenser on the return stroke.

If the rate of these pumps as meters could be determined at various velocities, the volume of water which they were delivering at any time, could be computed.

The following is a description of the apparatus used, and the results obtained in the experiment made previously to the trial of the ship's engines, which has not yet taken place.

It is expected that the trial will take place so soon as the ship comes out of the dock, where she is now receiving new decks and general repairs.

The following experiments were made with the pumps:

1st. To determine the volume of water that would be discharged through the plate in the bottom of the tank, at various heads, and with various numbers of the orifices plugged up.

2d. To determine the volume of water thrown by the pump at various velocities, and the power required.

To determine the amount of water discharged, the pump was run at a velocity required to maintain the desired head in the tank, and the water discharged through one orifice was received in an oil barrel, through a 3-inch iron pipe, one end of the pipe being curved up on a radius of 12 inches and adjusted under an orifice, so that the whole stream would fall directly into it; the other end being curved down to discharge into the barrel. The total length of pipe was 9 feet, and it was so supported that it could be adjusted under any orifice and made fast.

The spaces between the streams were large enough to allow the observer to notice that the whole stream was falling into the pipe, even when under the central orifice.

The barrel to receive the water, the contents having been carefully weighed and measured, was hung so that it could be swung under the end of the pipe at the instant desired, and, when full, dumped.

The time occupied in filling, and the mean head during the interval, were noted, and the experiment repeated a number of times. The position of the pipe was then changed to come under another orifice, and the experiment repeated, and so on until the mean discharge of all the orifices, at various heads, was determined.

The temperature of the sea water during these experiments was 74°, and the saturation, $\frac{24}{25}$ (July 8th, 9th, 10th, 11th).

The barrel contained 6·357 cubic feet.

It was found that when the depth of water over the plate was more than 3 feet, that there was no perceptible difference on the discharge of orifices in various parts of the plate; but that when the head became less than 3 feet, the discharge varied in different orifices, and at different times in the same orifice, under the same head.

This was true, whether all the 55 holes were open, or whether a portion of them were plugged. There could not be detected any difference in the flow, with a head of more than 3 feet, from a difference in the arrangement of the open and closed holes.

The following are the mean results of 49 experiments with a head greater than three feet:

Head of water above plate, in inches.	Cubic feet discharged by each orifice per second.
72·154	·1059
52·660	·0900
41·050	·0796

Fifty-four experiments on less heads than these gave results varying among themselves from zero to twenty-five per cent., and are therefore rejected.

The amount of water discharged from the same orifice at different heads should vary, if there were no causes of disturbance, as the square root of the heads.

The following comparison of the amount discharged actually and computed for the last two cases, by a comparison of the square root of the heads with the amount delivered in the first case, shows that the discharge does vary as the square root of the head, as the differences are within the errors of observation:

Head in inches.	Discharge by Experiment.	By Comparison.
72·154	·1059	———
52·660	·0900	·09019
41·050	·0796	·07964

The co-efficient of contraction being the ratio of volume of water actually discharged to that represented by the area of the orifice multiplied by the theoretical velocity, is

$$C = \cdot 7776.$$

The following table shows the number of cubic feet which will be discharged by each orifice during one hour at various heads, computed from experiments, by a comparison of the square root of the heads. If no opportunity should offer during the trial of the engines to test the capacity of the orifices, it will only be necessary to note the head of water in the tank, and to multiply the corresponding discharge from the table by the number of orifices open, in order to obtain the volume of water discharged per hour at any given instant.

The mean of these volumes (not the volumes corresponding to the mean head) will give the mean discharge of the pump for any number of observations.

The only apparent cause of error will be a change in the density of the water, either from more or less salt, or from a change of temperature; but the errors from these causes will probably be inappreciable.

NUMBER *of cubic feet which will be discharged in one hour from a single orifice at various heads, computed from experiment by a comparison of the square root of the heads.*

Head in inches.	Discharge.	Head in inches.	Discharge.
72	380·8	52	323·7
71	378·2	51	320·6
70	375·5	50	317·4
69	372·8	49	314·2
68	370·1	48	311·0
67	367·4	47	307·8
66	364·6	46	304·5
65	361·9	45	301·1
64	359·1	44	297·7
63	356·2	43	294·3
62	353·5	42	290·9
61	350·6	41	287·4
60	347·7	40	284·0
59	344·8	39	280·3
58	341·8	38	276·7
57	338·8	37	273·1
56	335·9	36	269.3
55	333·0	35	265·6
54	329·9	34	261·7
53	326·8	33	257·9
52	323·7	32	254·5

At the conclusion of the experiments upon the tanks, a series of experiments were made upon the pumps, to determine the volume of water delivered at various velocities, and the power required to work them.

These experiments were made by running one pump at a velocity necessary to maintain a constant head in the tank of nearly five feet, the engineer changing the throttle a little, in response to signals, when the head of water varied. It was found that the head could be maintained within two inches of that desired.

All the experiments were made with the same head of water in the

tank, more or less of the holes being plugged, in order to change the velocity of the pump in the different experiments.

In some of the experiments the pumps were run one hour, but it was concluded that as the head and strokes were so nearly constant, one half hour was sufficient for the latter portion of them.

The number of strokes was counted every 5 minutes during the hour trials, and every 2½ minutes during the half hour trials, during one minute, by a sand glass, which had been tested and found to be correct, and the mean head (when there was any variation) during the minute noted.

Indicator cards were taken every five minutes during the trial, from both the steam and water cylinder of the forward pump.

There were no indicator attachments on the after pump.

The scales of the indicator springs were found by experiment.

The stroke of the forward pump was 18¾ inches.

The stroke of the after pump could not be measured.

The following are the means of the result:

FIRST EXPERIMENT.

Which Pump.	Forward.	After.
Number of strokes, . . .	63·46	64·5
Head of water in tank, . .	61·115″	60·75″
Number of holes open, . .	30	30
Cubic feet of water per hour, .	10,530	10,572
Nominal volume of pump, . .	10,930	11,110
Per cent. of do. delivered, . .	96·4	95·2
Actual volume of pump, . .	10,510	
Per cent. of do. delivered . .	100·2	

SECOND EXPERIMENT.

Which Pump.	Forward.	After.
Number of strokes, . . .	79·643	85·458
Head of water in tank, . .	59·8″	61·041″
Number of holes open, . .	40	40
Cubic feet of water per hour, .	13,884	14,003
Nominal volume of pump, . .	13,715	14,720
Per cent. of do. delivered, . .	101·2	95·3
Actual volume of pump, . .	13,190	
Per cent of do. delivered, .	105.	

THIRD EXPERIMENT.

Which Pump.	Forward.	After.
Number of strokes,	95·8	99·2
Head of water in tank,	61·″	60·9″
Number of holes open,	48	48
Cubic feet of water per hour,	16,828	16,827
Nominal volume of pump,	16,500	17,080
Per cent. of do. delivered,	102·	98·5
Actual volume of pump,	15,870	
Per cent of do. delivered,	106·2	

It would, at first thought, appear impossible that any pump should deliver more water than the actual piston displacement, but it must be remembered that the conditions of these pumps are materially different from those generally tested.

In place of having to suck the water from a tank below, the pump cylinder is 2½ feet below the surface of the water, which would, if the piston were at rest, fill the barrel, and rise 2½ feet above.

The maximum velocity of the water in the suction-pipe is less than 4 feet per second, while the velocity due to a head of 2½ feet is more than 14 feet, leaving a margin of 10 feet velocity corresponding to a head of more than 1½ feet, tending to overflow the pump barrel.

This would account for an amount of water equal to the full displacement of the piston, for it will be seen hereafter that the head necessary to overcome the resistance of the valves and pipes is less than this difference.

To account for the excess of water delivered another cause appears.

The total length of all pipes from the sea to the pump, and thence through the condenser and overboard, is more than 70 feet. These pipes must be filled with a solid column of water, for there are no air vessels on the pump, and there can be no air in the water, except that drawn in through the Kingston valve in the bilge, 20 feet below the surface.

The mean velocity of the water in these pipes, at 100 strokes, is more than 3 feet per second.

When the pump piston has its maximum velocity it is pushing this column of water, but when it reaches the end of its stroke and suddenly stops, hesitating an instant before commencing a return stroke, the long column of water cannot be instantly stopped without burst-

ing all the pipes, but must, as in a hydraulic ram, continue in motion until its momentum is exhausted.

The velocity of 3 feet per second would carry it up about $1\frac{1}{2}$ inches in the standing pipe, if the piston should hesitate long enough.

The total travel of the water might be

$$18\tfrac{3}{4}''+1\tfrac{1}{2}'',$$

and the per cent. of piston displacement delivered

$$\frac{18\frac{3}{4}+1\frac{1}{2}}{18\frac{3}{4}}=108.$$

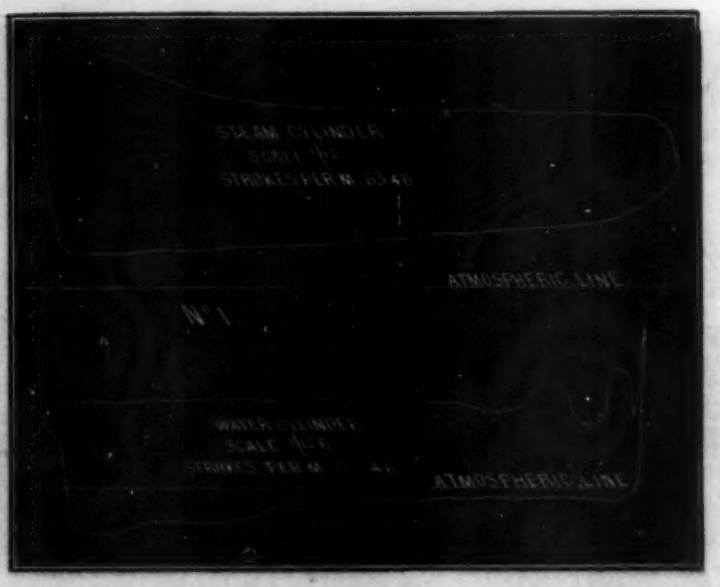
The maximum excess would be, at this speed, 8 per cent., which would be reduced by the resistance of the passages.

There can be no gain of efficiency from this cause, for although a portion of the water has gone through the pump without effort, when the piston commences its return stroke it will press on the water at rest, or nearly so, which must be set in motion at the expense of the steam.

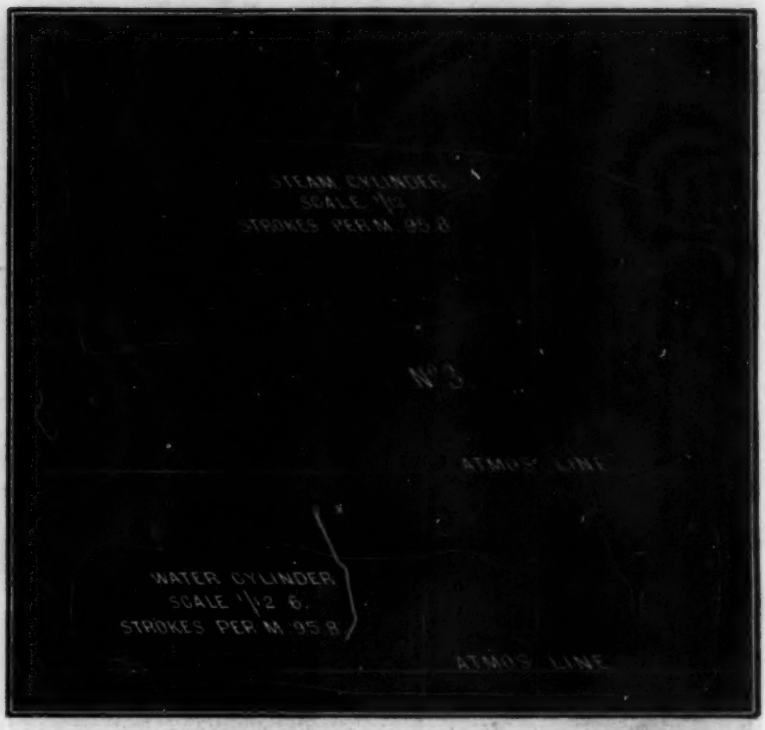
The shape of the indicator cards taken from the water cylinder appears to indicate that, during the first part of the suction stroke, the water was pressing on the piston, as explained above, and that the portion of the stroke through which that action lasts, increases as the pump runs faster, corroborating the measurements and foregoing theory.

The results computed from the indicator cards taken from the forward pump (copies of which are annexed to this paper), are as follows:

Number of strokes,	63·46	79·64	95·8
Steam, mean pressure,	8·6	9·72	10·62
" back "	2·77	6·24	9·34
" total "	11·37	15·96	19·96
Water, mean pressure,	7·118	7·673	8·83
Pressure necessary to work pump, steam pressure less water pressure,	1·482	2 049	1·78
	Mean	1·77	
Actual horse-power (one pump),	6·5	11·2	14·7
Actual horse-power at reduced head (one pump),	2·46	4·86	7·1


ATMOSPHERIC LINE
N° 1
ATMOSPHERIC LINE

STEAM CYLINDER
SCALE 1/2
STROKES PER M. 79 64
N° 2
ATMOS LINE
WATER CYLINDER
SCALE 1/2.8
STROKES PER M. 79 64
ATMOS LINE



APPENDIX.

The following computation of the head in feet, necessary to force the water through the pipes, valves and condenser tubes at the velocity corresponding to sixty strokes of the pump per minute, made previous to the experiment, according to the laws of hydraulics as laid down in Rankine's Civil Engineering, serves to check the accuracy of the experiment, and to show that the power necessary to work a circulating pump on ship board can be very approximately computed when the arrangement of pipes is known:

Assumed velocity of pump, 60 strokes per minute.

	Areas in square feet.	Velocity of Water in feet per second.
Tubes, . . .	2·698	1·028
Pipes, . . .	1·227	2·241
Pump, . . .	1·767	1·562
Valve ports, . .	1·1875	2.324
Strainer holes, . .	1·474	1·872

The losses of head considered are:

1st. Head necessary to give velocity.
2d. " " " overcome friction.
3d. " " " " resistance of bends.
4th. " " " " " " valves.

These have the following values:

To give velocity, . . $h = \frac{v^2}{2g}$.

Tubes, . . .	$h =$	·0602
Pipes, . . .	"	·2337
Pump barrel, . .	"	·0758
Valve ports, . .	"	·1677
Strainer, . . .	"	·0543
		·5917

To overcome friction $h_2 = F\frac{v^2}{2g}$,

in which F is a factor depending upon the form and material or the passage.

Tubes, . . .	$h_2 =$	·275840
Pipes, . . .	"	·089280
Pump barrel, . .	"	·000222
Valve ports, . .	"	·001310
Strainer, . . .	"	·004388
		·384040

To overcome resistance in bends, being an amount depending upon the number and abruptness of bends, $h_3 = 1{\cdot}1664$.

To overcome resistance of springs on back of valves:

Area of rubber disc, 50 square inches.
Strength of spring, 45 lbs.
Estimated lift, $\frac{1}{8}$ inch.
Press per square inch, $\frac{9}{10}$ lbs.

Loss of head:

Receiving valve, $h_4 =$	1·8
Delivery "	1·8
	3·6

Friction and bends in external pipe:

$$h_5 = 0860.$$

Total resistance at 60 strokes:

$$h_1 = \cdot 591700$$
$$h_2 = \cdot 384040$$
$$h_3 = 1 \cdot 664000$$
$$h_4 = 3 \cdot 600000$$
$$h_5 = \cdot 086000$$
$$6 \cdot 325740$$

Total loss from friction at 60 strokes:

$$h_1 = \cdot 59170$$
$$h_2 = \cdot 38404$$
$$h_3 = 1.66400$$
$$h_5 = \cdot 08600$$
$$2 \cdot 72574$$

Total loss from friction at 63·46 strokes:

$$\frac{(63 \cdot 46)^2}{(60)^2} \times 2 \cdot 72574 = 3 \cdot 049$$

Resistance of valves, . . .	3·600
Statical head in pipe, . . .	11·000
Computed head equivalent to resistance, .	17·649
Experimental head equivalent to resistance, being mean pressure + height of water above the pump, . . .	16·460
Difference, ...	1·278
Error of computed resistance in per cent. of actual resistance, . . .	6¼

This error probably arises from the valves not lifting as much as $\frac{3}{4}$ inches, and therefore the springs on the backs of the receiving and delivery valves not offering the resistance stated.

TEST TRIAL OF THE LYNN PUMPING ENGINE.

SECOND REPORT OF THE BOARD OF ENGINEERS, TO THE PUBLIC WATHR BOARD OF LYNN, MASS.

[Continued from Vol. lxviii, page 414.]

MEASURES OF CAPACITY OF PUMP.

The overflow from the stand-pipe at the reservoir was conveyed by a wooden trunk into a weir box 15 feet long, 6 feet wide and 4 feet 6 inches deep. The weir was at the opposite extremity from the trunk. Its crest was 2·11¾ feet above the bottom of the box, and 3·73 feet wide, and placed centrally in the end of the box. That the water should approach the weir with as uniform flow as possible, two racks covered with wire cloth were placed between the trunk and the weir. The arrangement of weir and mode of taking heights of water were like those adopted by Mr. Francis in his "Lowell Hydraulic Experiments." The readings were every 2½ minutes, and as the heights varied but little they have been averaged as giving a result sufficiently near. The discharges have been calculated by Mr. Francis' Tables and the correction for velocity of approach from his formula.

The readings were taken from 3 P. M. to 6 P. M., December 10, and from 3 P. M. to 6 P. M., December 11. Readings would have been taken the 12th, but the filling of the reservoir by the pumping disturbed the supports of the weir box.

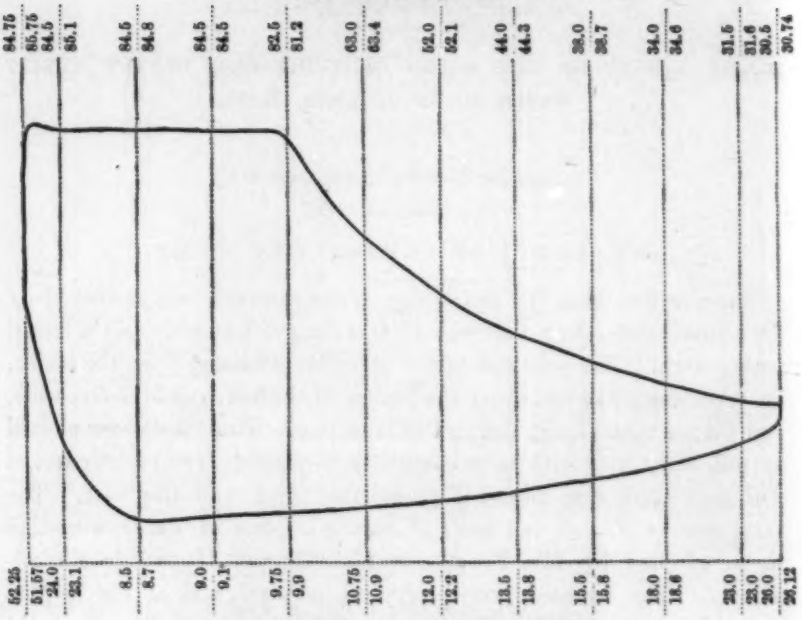
The average height on the 10th was			0·743
" " " 11th was			0·739
Discharge from 3 P. M. to 6 P. M., December 10th	7·666	cubic feet per second.	
" " " " " 11th	7·606	" " "	
Leak of weir measured and estimated	0·0092	" " "	
Revolutions of engine during 3 hours, from 3 P. M. to 6 P. M., Dec. 10th,			3,303.
" " " " " " " 11th,			3,314.
Capacity of pump by weir, measured December 10th			187·49 galls.
" " " " " 11th			185·41 "
Average			186·45
Add for leak at weir		·23	186·68 "
Measured capacity			194·37 "

$$\frac{186.68}{194.37} = .9601.$$

Loss of action of pump as given in the first report, 4 per cent.

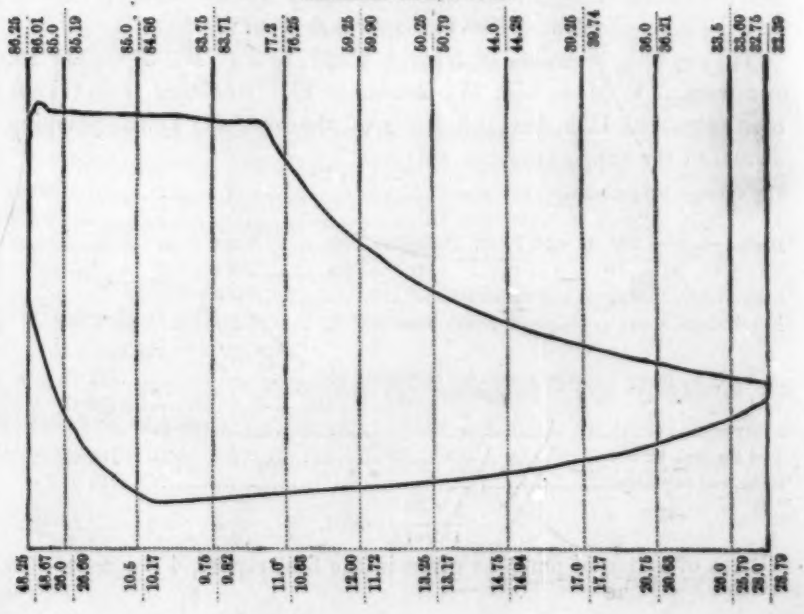
HIGH PRESSURE CYLINDER—TOP.

DECEMBER 11TH, 6 A. M.



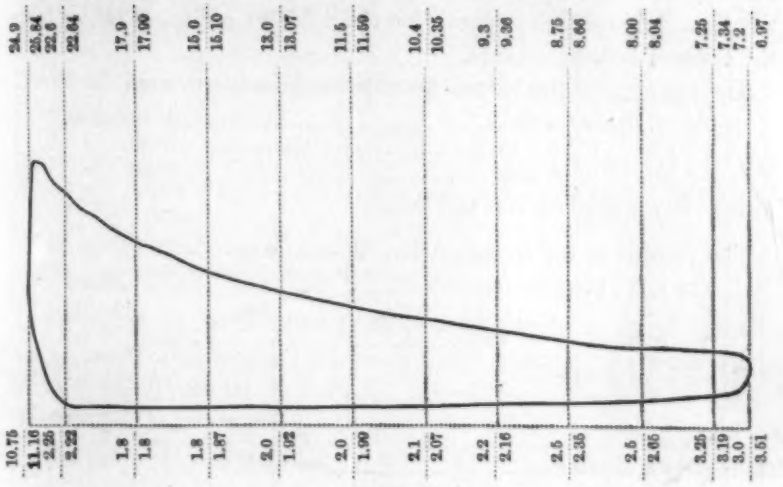
HIGH PRESSURE CYLINDER—BOTTOM.

DECEMBER 12TH, 3 A. M.



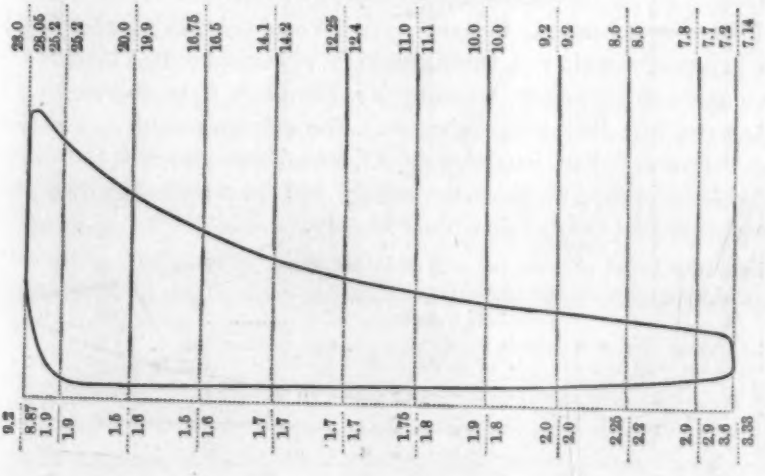
LOW PRESSURE CYLINDER—TOP.

DECEMBER 11TH, 11 P. M.—AND AVERAGES.



LOW PRESSURE CYLINDER—BOTTOM.

DECEMBER 12TH, 2. A. M.—AND AVERAGES.



The cards, as given in the cuts, are representations of cards taken by the indicators. The figures to the left of the lines show the pressures as measured by the scales of lbs.—the figures to the right of the lines, the average pressures on the different ordinates taken from the table of indicator cards.

The readings of the barometer at the engine house were :—

9 A. M.,	December 10th	30·10 inches.
5 "	" 11th	30·30 "
3 P. M.,	" 12th	29·68 "

with nearly a gradual rise and fall.

The records at the signal station, Boston, were:—

7.58 A. M.,	December 10th	30·070
7 "	" 11th	30·276
2 P. M.,	" 12th	29·658

Records of gauge—

	Extremes.	Average.
Vacuum...	27¾ to 28½ in.	28 in.
Steam gauge in engine room	65 to 72 lbs.	70½ lbs.
(Corrected.)		
" on boiler No. 1	69½ to 75½ lbs.	73½ "
" " No. 2	70 to 76 "	74 "
Water gauge in engine room	63·6 to 64·6	64·20

This last gauge was that employed to determine the pressure on the water piston, and it will be seen by reference to our first report that reducing the height of the gauge above the average height of water in the well to pounds, and estimating friction in this lower portion of the main at 1 pound; the pump piston is credited with a load of 73·41 pounds per square inch. During the night of December 10-11 and 11-12 a number of cards were taken by Mr. Hermany from the centre of the pump by a Hopkinson indicator. The average pressure, as shown by the cards taken December 10-11, was 73·66 lbs., and December 11-12, 72·75 lbs., of which the average will be at little less than the load estimated in our calculations of duty.

The average length of stroke from the cards, before the cut-off on the high-pressure cylinder was at	top	0·337	of stroke.
	At bottom	0·325	"
The average closing of exhaust was in high-pressure cylinder,	top	0·858	"
	Bottom,	0·841	"
Low "	Top	0·938	"
	Bottom,	0·940	"

READINGS OF THERMOMETERS.

	Extremes.	Average.
Steam in engine connection	321° to 326°	324°
Smoke in boiler flue	310 to 350	333
Feed water from measuring cask	91 to 97	95
" " " donkey connection	91 to 98	95
Condensed water at its discharge into pump-well	88 to 92	91

WELL.

Pump well	40 to 42	41
Air outside engine house	24 to 38½	32
	ft. in. ft. in.	ft. in.
Water in well—depth	7 10½ to 8 1	7 11¼
Depth of overflow of stand-pipe at reservoir	6 inches.	

Referring to the last column of preceding table, it will be seen that at 11 A. M., December 10th, the average level of the water in the boilers was 0., whilst at 3 P. M., Dec. 12th, it was + 3-16 inch, or about 143 lbs. of water in excess in the boilers at the close of the trial over what it was at the commencement. It was discovered Dec. 11th that there was a small leak from the boilers through the blow-off pipe, which continued throughout the trial, and this leak was found, by catching it in a pail and weighing, to be at the rate of 22 lbs. per hour. 22 lbs.×52 hours,+143 lbs.=1,287 lbs. These 1,287 of water were raised from 95°, the average temperature of the feed, to 324°, the average observed temperature of the steam, which, on the basis of the evaporation during the trial, from 95° to 1,179°, would require 317 lbs. of coal. No account of this small item was taken in our estimate of duty.

At the close of the trial for duty and capacity, an experiment was made to determine the quantity of steam condensed in the jackets of the steam cylinders. The return pipe to the boiler was disconnected and the water as condensed in the jackets was allowed to drip into a pail, and as the pail was full the time was noted and contents weighed. The rate of condensation was found to be nearly uniform, and the quantity condensed in 56½ minutes, 69 lbs. at 98°, or if referred to the 52 hours duration of the trial, 3,810 lbs. were during that time condensed in the jackets.

In conclusion, the records now submitted in this our second report, without any deductions or inferences therefrom, will be found full and sufficient to enable any one interested in and conversant with such matters to estimate the work done at engine and pump, the

friction of rising main, and the evaporation of water per pound of coal, or per pound of combustible, at any standard of temperature; thus affording means of comparison with former experiments on pumping engines; and at the same time presenting in a preservable form data which we trust will be valuable for future reference.

W. E. WORTHEN, JAS. P. KIRKWOOD,
J. C. HOADLEY, CHAS. HERMANY,
JOSEPH P. DAVIS.

New York, June 1st, 1874.

APPENDIX.

First Report of the Board of Engineers on the Test Trial of the Pumping Engine at Lynn, Mass.

Gentlemen:—Agreeably to your request, we have made a test trial of the pumping engine connected with your works, and now respectfully present this our first report.

The character of the engine being entirely different from that prescribed in the original specifications, it seemed to us that the manner of conducting the experiment, and of determining the capacity and duty of the engine, was left without restriction to our judgment, and in this view your chairman concurred.

As the pumping engine at Lowell is very similar to yours in construction and performance, we have followed the modes of test that were adopted at the late trial there.

The engine was started at 8.50 A. M., December 10, 1873, but the test was not considered to have commenced till 11 A. M., and it was concluded at 3 P. M., December 12, making the duration of the trial fifty-two hours, without stop. The engine at the conclusion of the test continued its work, the fires and water in the boilers being kept as uniform as possible, and the duration of the experiment was established by inspection of the firing as shown on the coal profile plot. The capacity of the pump was determined by weir measures at the reservoir—three hours, from 3 P.M. to 6 P.M., December 10, and three hours, from 3 P.M. to 6 P.M., December 11—and the actual delivery was found to be ninety-six per cent. of the capacity as given us by Mr. Leavitt, the mechanical engineer who designed the machine. The capacity of the full pump is 194.37 gallons; the delivery per revolution, as determined by weir measurement, was 186.55 gallons; the number of revolutions made in the fifty-two hours was 57,357; and the total quantity of water delivered at the reservoir during that time, 10,700,163 gallons—or the delivery was at the rate of 205,772 gallons

per hour. The delivery required by the terms of the contract is 200,000 gallons per hour.

The duty was established as follows:—The area of the pump, by our measures of the diameter, is 534.53 square inches.

The load was determined from a gauge on the main, near the pump, the average reading of which was	64.20 lbs.
The difference of level between centre of guage and surface of water in the pump-well, reduced to pounds	8.21 lbs.
Allowance for friction and bends of main, between guage and pump-well, as at Lowell	1.00 lbs.
Total pressure per square inch	73.41 lbs.

The length of stroke, as measured, was seven feet.

From the above data, and the number of revolutions, the work done at the pump was determined, no deduction having been made for loss of action. The coal was picked Lackawanna coal, and the contractor was allowed to make use of any coal from the cinder that he deemed of value as combustible, but no credit has been allowed for screenings or unconsumed coal. The coal has been charged against the machine in gross, and the total quantity fed into the furnaces during the fifty-two hours was 15,160 pounds. The division of the foot-pounds of work by the weight of coal determined the duty, and the result is 103,923,215 foot-pounds for every one hundred pounds of coal fed into the furnaces.

The duty given by your engine is, so far as we are aware, the highest that has ever been obtained by trial test of any pumping engine in this country, and we believe that in the future it will make a good record for itself—a record that will confirm the wisdom of your action in adopting so novel a form of machine. The arrangement of parts, though unusual, appears judicious, and to have been well considered. The framing is particularly worthy of mention, as showing a distribution of material favorable for strength and rigidity.

EFFICIENCY OF FURNACES BURNING WET FUEL.

AS DETERMINED BY EXPERIMENTS ON A LARGE SCALE.

By Professor R. H. Thurston, A. M., C. E.

A Paper read before the American Society of Civil Engineers, October 21st, 1874.

(Continued from Volume lxviii, page 404.)

16. A very neat apparatus has been invented by Leicester Allen, of New York, for determining the quality of the steam furnished by a steam boiler. One of these instruments was made under the direc-

tion of the writer, for a committee of the American Institute, and used in 1872, together with the apparatus already described, at the American Institute Exhibition of that year.

17. At the trial about to be described it was impossible to condense all of the steam made, and as no "Allen Calorimeter" was obtainable, it became necessary to improvise apparatus for the occasion. The steam-pipe leading to the engine was tapped by a piece of gas-pipe, on which was fitted a stop-valve. From a short piece of pipe attached to this stop-valve a length of india-rubber hose was led to a convenient point beside the boilers, where a barrel was mounted on an accurate platform scale, 200 pounds of water were carefully weighed into this barrel, and when the scale beam precisely balanced, the weight was set ahead 10 pounds. A very accurate thermometer, which had been provided by the writer, completed this crude yet satisfactory arrangement.

At intervals during the trial the stop-valve was opened, and after allowing steam to blow through the hose freely until all water was expelled, and the hose was so thoroughly heated as to insure that no loss of heat, by the steam flowing through it, should produce condensation and render the results inaccurate, the end of the pipe was plunged into the water contained in the barrel, and the issuing steam allowed to condense until the rise of the scale beam proved 10 pounds of steam to have been added to the weight originally placed in the barrel. The temperature of the water was carefully observed at the beginning and at the end of the experiment, and the rise of temperature recorded as a basis for the estimates of priming to be given.

18. It was considered advisable to ascertain, if possible, the temperature of the products of combustion escaping to the chimney. No pyrometer was obtainable, and it became necessary to improvise another arrangement for this purpose. A mass of iron, weighing 60 pounds, was found and placed in the flue leading from the boiler, where it, after a time, attained the temperature of the gases flowing past it. A wooden vessel of convenient size and shape was obtained, and 50 pounds of water were carefully weighed into it. At intervals of two or three hours the iron was suddenly removed from the flue and dropped into this water. The initial and final temperatures were noted, and, with the range, recorded for use in calculating the temperature of the waste products of combustion. The pressure of steam was observed hourly.

19. The collated observations gave the following data:

Mean steam pressure during trial.....71.4 pounds,
Total amount of spent tan burned.....7.7 cords.
" " " water fed to boilers.....73125 pounds.
Temperature of water entering boilers.....190° Fah.
" " in determining priming:

	Initial.	Final.	Range.
1st observation.....	60°	110°	50°
2d "	63°	124 (116°?)	53°(?)
3d "	62°	115°	53°

Temperature of water in determining temperature of flues:

1st observation.....	65°	119°	54°
2d "	63°	122°	59°

Weight of one cord of wet spent tan, as measured in the leach.....5447.7 pounds.
Length of trial.....13 hours.

20. The determination of the total heat derived from the cord of fuel is the first and most important problem. To solve it, it is necessary to know the temperature and weight of feed water, the weight of steam produced and its temperature, the weight of water heated to the temperature of the steam, but not evaporated, and the quantity of fuel consumed. From the data obtained we can readily ascertain the total number of units of heat utilized per cord of wet fuel burned.

21. It is first necessary to calculate what portion of the 73,125 pounds of water passing through the boiler, was actually evaporated.

Each pound of steam produced, required for its generation the quantity of heat needed to raise it from the temperature of the feed-water to that due the pressure under which it was formed, and to vaporize it at that temperature.

Each pound of water, carried away in suspension by the steam, only absorbed from the fuel the amount of heat needed to raise its temperature from that of the feed-water to that of the steam.

In heating the water in the calorimeter used in testing its quality, each pound of steam gave up an amount of heat equal to that which would have been required to raised its temperature from that of the mass in the calorimeter at the end of the experiment, to that of the steam in the boiler, and to evaporate it at the latter temperature and pressure.

Each pound of water entering the calorimeter, surrendered a quantity of heat equal to that needed to raise its temperature from the final temperature of the calorimeter to that of the steam under boiler pressure.

22. The total amount of heat being the sum of these two quantities, we may construct an algebraic equation which shall embody all the conditions of our problem.*

Let H = the number of heat units per pound of steam, h = the number of heat units per pound of water, U = total heat transferred to calorimeter, W = total weight of steam and water, x = total weight of steam alone, $W - x$ = weight of water alone.

$$\text{Then } Hx + h(W-x) = U; \text{ or, } x = \frac{\frac{U}{h} - W}{\frac{H}{h} - 1}.$$

23. At the first experiment, the steam pressure, per gauge, was 75 pounds. The temperature of steam at this pressure is 320° Fahr. The "total heat" of steam at 320°, from 0° Fahr., and at 75 pounds pressure, is (320 — 212) 0·305+212+66·6=1211·5°.

The heat transferred to the calorimeter, per pounds of steam, was therefore 1211·5 — 110=1101·5 thermal units in this experiment.

The heat transferred, per pound of water, was 320 — 110=210 thermal units.

The total quantity of heat transferred to the 200 pounds of water, by 10 pounds of mingled steam and water, was 200 (110°—60°)= 10,000 thermal units.

$$\text{Finally, } x = \frac{\frac{10000}{210} - 10}{\frac{1101{\cdot}5}{210} - 1} = 8{\cdot}87 \text{ pounds steam.}$$

$$W - x = 10 - 8{\cdot}87 = 1{\cdot}13 \text{ pounds of water.}$$

The percentage of priming was, therefore, 11·3. The ratio of weight of steam and water was $\frac{8{\cdot}87}{1{\cdot}13} = 7{\cdot}85$, the water being $\frac{1{\cdot}13}{8{\cdot}87} \times 100 = 12{\cdot}74$ per cent. of the steam.

24. The other experiments were made with the steam pressure as before, and, in the second, the valve of $W - x$ comes out negative, indicating superheating. This may, possibly, have actually occurred as a consequence of the water having fallen slightly below the upper row

*See Report of Committee on Test of Steam Boilers; Trans. Am. Inst., 1871-2.

of tubes in one boiler, but it is more probable that the reading, 124°, does not represent the mean temperature of the mass of water in the calorimeter. In this experiment, the water was not as carefully stirred with the thermometer as in the other experiments, and the temperature was taken at the surface of the water, after a first and otherwise satisfactory reading of 116° had been obtained, but a second application of the steam jet had been necessary, to accurately balance the scale, which heated the surface above the average temperature of the mass previously heated. The true reading can probably have been no higher than 116° or 117°, and it is taken for purposes of calculation at the former figure, although the lowest unrecorded reading, finally, actually obtained at the middle of the well stirred mass was 116°.

$$\text{Then } x = \frac{\frac{10600}{204} - 10}{\frac{1095{\cdot}5}{204} - 1} = 9.6 \text{ pounds steam,}$$

and the weight of water being $10 - 9{\cdot}6 = 0{\cdot}4$, the percentage of priming was 4, and the water carried over weighed $\frac{0{\cdot}4}{9{\cdot}6} \times 100 = 4{\cdot}3$ per cent. as much as the steam with which it was mingled.

In the third experiment

$$x = \frac{\frac{10600}{205} - 10}{\frac{1096{\cdot}5}{205} - 1} = 9{\cdot}59\,; \; W - x = 0{\cdot}41.$$

The percentage of priming was 4·1, and of water to steam 4·2 per cent.

The mean percentage of priming was 6·47. The mean percentage of steam alone was 93·53.

25. The total quantity of heat derived from the fuel and taken up by the boilers can now be divided into two portions and each calculated.

The total weight of steam produced was $73125 \times {\cdot}9353 = 68393{\cdot}8$.

" " water primed " $73125 \times {\cdot}0647 = 4731{\cdot}2$.

The mean pressure at which this steam was formed being 71·4 pounds, we find its "total heat" per pound to be 1210·6 thermal

units, and the heat communicated to each pound of feed entering at 190°, and evaporated at this pressure, 1020·6 units. The average heat received from the fuel by each pound of water not evaporated was 127 thermal units.

Then $68393{\cdot}8 \times 1020{\cdot}6 = 69802712{\cdot}3$ units,

and $4731{\cdot}2 \times 127{\cdot}0 = 600862{\cdot}4$ "

Total heat from the fuel $= 70403574{\cdot}7$ thermal units.

$$\text{Total heat per cord of tan} = \frac{70403574{\cdot}7}{7{\cdot}7} = 9143321{\cdot}4 \text{ units.}$$

26. the usual standard, as generally accepted by Engineers in examples of this kind, is the evaporation of one pound of water, at the boiling point, and under atmospheric pressure.

The heat required is the latent heat at 212°, or 966·6 thermal units per pound. We have therefore—

Equivalent evaporation, by one cord of wet spent tan, from 212°, under atmospheric pressure:

$$\frac{9143321{\cdot}4}{966{\cdot}6} = 9459{\cdot}2 \text{ pounds of water.}$$

27. Under these conditions, 10 pounds of water would be considered a fair evaporation per pound of good coal, and in this example, therefore, the furnace utilized from each cord of tan the equivalent of 946 pounds of coal.

28. A quantity of the tan was placed in a "fruit jar," and hermetically sealed. This tan was carefully weighed by Professor Geyer, at the Stevens Institute of Technology, was dried by exposure to the air in the study of the writer for one week, and then was again weighed by Prof. Geyer, in the presence of the writer. The weights, before and after drying, were respectively 656·8 grammes, and 268·8 grammes. This fuel contained, therefore, 59 per cent. water, and but 41 per cent. woody fibre.

The weight of a cord of this tan, measured in the leach, and then well dried in the open air, would be 2233·56 pounds, and the equivalent evaporation per pound becomes 4·24 plus that of the water contained in the fuel, say 1·44, or 5·68 pounds water per pound of combustible.

29. The determination of the temperature of chimney flue, or of the escaping gaseous products of combustion, is thus made. At the

first observation, 50 pounds of water were heated from 65° to 119° Fahr., a range of 54°, by the cooling of a mass of iron weighing 60 pounds, from an unknown temperature to 119° Fahr. The amount of heat communicated to the water was $50 \times 54 = 2700$ thermal units. Each pound of iron, therefore, parted with $\frac{2700}{60} = 45$ units of heat.

The specific heat of iron is given by Watts as 0.112. It requires, therefore, the cooling of one pound of iron through nine degrees of temperature to heat a pound of water one degree. The iron, in the case considered, must therefore have lost $45 \times 9 = 405°$ Fahr., when cooled to 119°, and its original temperature, and that of the escaping gases in the flue, must have been $405° + 119 = 524°$ Fahr.

The second observation in a similar manner, gives the temperature of the chimney flue at 564°·5 Fahr.

Watts gives 315° centigrade, 599° Fahr., as a proper temperature with natural draft.

Rankine gives absolute temperature of external air multiplied by $\frac{25}{12}$ as the temperature giving most effective draught. In this case, therefore, in which the average temperature of the air was 74°, the best temperature of chimney would have been $\left(25\frac{74+461}{12}\right) - 461 = 645°$ Fahr.

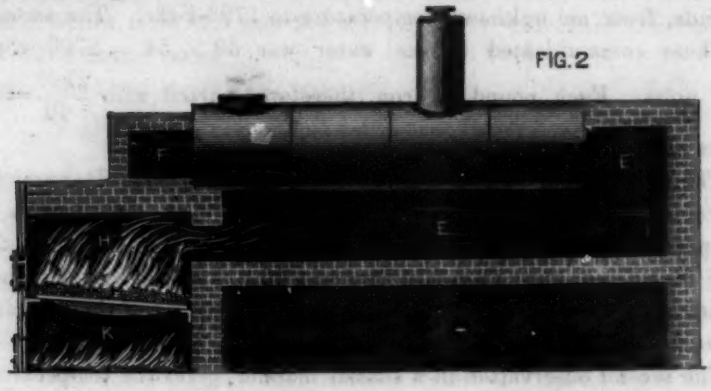
30. The minute inaccuracy of the results thus obtained, which is due to changes of the specific heat of water, and of metal, under varying temperatures, is of no practical importance. As the vessel containing the water heated was of wood, in each case, the usual correction for heating the vessel when metallic becomes of no importance also, and the weight of the thermometer being insignificant in comparison with that of the water, that correction is unnecessary. This method is of great value as a last resort, in absence of other good heat measuring appliances.

THE CROCKETT FURNACE.

31. The second furnace which was experimented upon by the writer, was of the form known as the "Crockett." This form of furnace is shown in Fig. 2, and that here described was of the same

general form as that illustrated, differing principally in its arrangement of bridge walls.

FIG. 2



In this example two furnaces were constructed side by side, each having a grate surface of 4×6 feet, the total grate area of both being 48 square feet.

The grates were of cast iron, of ordinary form, set so closely that none of the wet fuel could fall through into the ash-pit. It was stated that it was not intended that the charred fuel should fall through and burn in the ash-pit.

During this trial, however, more or less burning tan was continually falling into the ash-pit and burning there. This, undoubtedly, assisted, in some degree, in the desiccation of the wet fuel, by direct radiation of heat, and by heating the entering air as it passed over this bed of hot coals. To this extent the furnace resembled, in its action, the Thompson furnace, already described.

Above the grates a brick arch was turned, as shown, against which the products of combustion impinged and the heat radiated from the burning fuel on the grate, keeping this arch at a high temperature, it assisted the process of desiccation of wet fuel, when first thrown in, by strongly radiating upon it the heat thus stored up while the fires were most intense. From the furnace the gases passed directly into the flues beneath the boiler.

32. The tan, wet from the leach, was charged into the furnaces through the doors in the front, as in all usual forms of furnace, and the process of "firing" differed but little from that usual with thin fires, where coal is used. The fuel was thrown in at intervals of between 5 and 8 minutes, the furnace-man taking care, first, to fill all

holes in the burning mass, and, next, covering the whole with a very evenly distributed and very thin layer of fresh fuel. This fresh charge was quickly dried by the heat of the burning fuel, over which it was spread, and by the heat radiated from the hot furnace arch above it, and, taking fire, burned freely. No special effort seemed to be made to obtain "alternation" in working the furnace, but the irregularity with which the fuel burned at different parts of the grate did, perhaps, secure something of this effect.

33. The fuel was measured in the leach, as in the previous case, and about a half leach, measuring 4½ cords, was burned during the trial, between 8 o'clock A. M. and 6 o'clock P. M. The actual working time was 9 hours, the work being stopped from 12 M. to 1 P. M.

34. The tan bark burned was hemlock, mixed with some oak. It looked like a better material than that used in the other trial. It was more cleanly ground, seemed less "soggy," and had a much better color.

35. The boilers used here were two in number. One was an old-fashioned "Cornish" boiler, 4 feet in diameter and 18 feet long, with one 24-inch flue. The second was 6 feet in diameter, with four 18-inch flues; the total length was 15 feet. The gases from the furnace were led under the boilers, and then, with a double return through the boiler-flues to the chimney. The total heating surface, reckoned as before, was very closely 700 square feet.

36. The flues were stated to have been so long in use without cleaning, that the draught was somewhat impeded by the accumulation of ashes beneath the boilers, and that the rapidity of combustion was somewhat lessened. The two trials are, therefore, both to be taken as representing less than the maximum capacity of the furnaces.

37. The trial was made by a somewhat similar method to that adopted in the one already described. The quality of steam was determined similarly. The water was measured differently. In this case the capacity of the feed-pump exceeded several times the requirements of the boiler, and the only absolutely reliable means of determining the quantity of fuel seemed to be to measure every pound going to the pump, thus evading the uncertainty attending any attempt to secure regularity in the action of the latter.

38. A barrel was fitted to the suction-pipe of the pump, and an employé of the Mechanical Laboratory of the Stevens Institute of Technology was stationed with a hose to fill it with water, when it

became empty, and to keep an account of the number of barrels used, while an employé of the proprietors of the tannery, stationed at the pump, checked the account. All of the water fed into the boilers during the trial was thus measured, and at the close of the trial the barrel was taken out, filled on the scales, and the weight of its contents determined.

39. There was no opening into the chimney flue through which the escaping gases could be reached, and their temperature was not determined.

40. The amount of smoke issuing from the chimney of this furnace was considerably greater than was observed at the preceding trial, indicating that the Thompson Furnace secured a somewhat more perfect combustion than the Crockett.

41. The results of this trial gave the following data:

Total number of cords of tan burned, . . . 4·5
" weight of water fed to boilers, . . . 28 509 pounds.
Temperature of feed-water entering boilers (estimated), 160° Fahr.
" water observed in determining "priming":

	Initial.	Final.	Range.
1st observation, . . .	68°	118°	50°
2d " . . .	70°	118°	48°
3d " . . .	76°	126°	50°
4th " . . .	76°	124°	48°

Length of trial, ... 9 hours.

42. Estimating the priming as before, we obtain from the several observations, which were made with the steam pressure, per gauge, 55, 50, 45 and 60 pounds, respectively, $x = 9{\cdot}02$, $x = 8{\cdot}07$, $x = 9{\cdot}12$, and $x = 8{\cdot}55$, and the percentage of priming, 9·8, 19·3, 8·8, 14·5 per cent. The mean of all observations gives the average percentage of priming at 13·1 per cent., and indicates that the steam issuing from the boiler carried in suspension 15 per cent. of its own weight of unevaporated water.

43. We determine the total heat from the fuel thus:

Steam produced, . . . $28\,509 \times 0{\cdot}869 = 24\,774{\cdot}32$ pounds.
Water primed, . . . $28\,509 \times 0{\cdot}131 = 3\,734{\cdot}68$ "

The mean pressure of steam during the trial was 50·44 pounds per square inch, and its temperature 298° Fahr. Its total heat at 298° from 0° was 1204·8 units per pound. Then we have

Total heat, per pound of steam	1204·8 — 160 =	1044·8
" " water	298 — 160 =	138, and
Total heat transferred from fuel to steam	25 884 209·54	units.
" " " water	515 385·84	" and hence
Total heat transferred from fuel to feed	26 399 595·38	units.
" per cord of wet tan	6 866 576·75	"
Equivalent evaporation per cord, water at 212°	7 103·84	pounds.
" weight of coal per cord of tan	710·38	"

44. A sample of the fuel used in this trial was sealed up, as before, and was similarly weighed at the Stevens Institute of Technology, dried in the air one week, and its loss of moisture determined.

This sample contained 55 per cent. of water, and 45 per cent. ligneous material. The weight of the tan in the leach was judged to be practically the same as in the preceding trial, and the equivalent evaporation per pound is $\frac{7103{\cdot}84}{2233{\cdot}56} = 3{\cdot}19$ plus the water held by the fuel, say 1·22, or 4·41 pounds.

(To be Continued.)

[Entered according to act of Congress, in the year 1873, by John Richards, in the office of the Librarian of Congress at Washington.]

THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

By J. Richards, Mechanical Engineer.

[Continued from Vol. lxviii, page 425.]

DESIGNING MACHINES.

It will hardly be expected that any part of these articles that are intended mainly for apprentices, should relate to designing machines, yet there is no reason why the subject should not to some extent be studied from the beginning of a course.

There is, perhaps, no one who has achieved a successful experience as an engineer but will acknowledge the advantages derived from early efforts to generate original designs, and at the same time, admit that if these first efforts had been properly directed, the advantages gained would have been greater still.

There is nothing more difficult, in the absence of experimental knowledge, than for an apprentice engineer to discriminate and choose plans for his own education, or to determine the best way of pursuing such plans when they have been chosen; and there is nothing that consumes so much time or is more useless than making original plans, if there is not some systematic method followed in such attempts.

There is no object in preparing designs, when their counterpart may already exist, so that in making original plans, there should be some knowledge of what has been already done in the same line; it is not only discouraging, but annoying, after studying a design with great care, to find that it has been anticipated, and that the work has been one of reproduction only; for this reason, attempts to design should at first be confined to familiar subjects, instead of venturing upon unexplored ground.

Designing is in many respects the same thing as invention, except that it deals more with mechanism than principles, although it may, and often does include both. Like invention, designing should always be attempted for the attainment of some definite object laid down at the beginning, and followed persistently throughout; without such an object the time spent in designing is apt to be lost.

It is not always an easy matter to hit upon an object to which designs may be directed; and although at first thought it may seem that any machine or part of a machine is capable of improvement, it is no easy matter to define existing faults nor to conceive of plans for their remedy.

A new design should be predicated upon one of two suppositions, either that existing mechanism of the same kind is imperfect in its construction, or that it lacks functions that the new design may supply, and if those who spend their time in making plans for novel machinery would stop to consider this fact before beginning, it would save no little time that is wasted in what is termed scheming without a purpose.

Aside from determining the precise object of an improvement, and arriving at the principles of operating in the preparation of designs, there is nothing connected with constructive engineering that can be more nearly brought within general rules and principles than that of detailing machines. I am well aware of how far this statement is at variance with popular opinion among mechanics on this subject, and

also of the very thorough knowledge of machine application and machine operation that is required in making designs, and mean, that when the premises are once laid down, there are certain principles and rules that may determine their arrangement and distribution of material, the position and relation of moving parts, so that a machine may be built up without any more risk of mi take than in building a house.

Designing machines includes their adaptation, endurance and cost. Adaptation referring to the performance of machinery, its commercial value, or what the machinery may earn in operating, as compared to hand labor. Endurance, to the time that machines may operate without detention for repairs, and the constancy of their performance; and cost, to the investment represented in the machinery, which must be in proportion to the nature and amount of the work performed.

The adaptation, endurance, and cost of machines, may be resolved into movements, arrangement of parts, and proportions. Movements and strains may be called the base upon which designs for machines are based; movements determining the general dimensions, and strains the proportions and sizes of particular parts. Movement and strain determine the nature and area of bearings and bearing surfaces.

The range and speed of movements in machines are elements in designing that admit of a definite determination from the condition of their operation, but arrangement cannot be so determined and is the most difficult point to find data for in preparing original designs. To generalize, there must be, in designing:

First, a conception of certain functions or an object which the mechanism is to accomplish.

Second, plans of adaptation and arrangement of the component parts of the machinery, or organization as it may be called.

Third, a knowledge of specific conditions, such as strains and the range and rate of movements.

Fourth, there must be proportions of the various parts, including bearings and bearing surfaces.

To illustrate the practical application of these propositions, let it be supposed, for example, that a machine is to be made for cutting the teeth in gear racks, of three-fourths inch pitch and three inches face, and that we are to set out to prepare a design from original premises and without any reference to such machines as may be in use for this purpose.

It is not proposed that an actual design shall be made that will by words alone convey a comprehensive idea of an organized machine, but to proceed by a course that will illustrate the plan of reasoning that is most likely to attain a successful result.

The reader, in order to understand what is said, may keep in his mind a shaping machine with crank motion, a machine that very nearly fills the segments of cutting tooth racks.

Having assumed a certain work to do, the cutting of tooth racks three-fourths inch pitch and three inches face, the first thing to be considered will be, is the machine to be a special one, or one of general adaptation? This question has to do, first, with the functions of the machine in the way of adapting it to the cutting of racks of other sizes, or other kinds of work, and secondly, as to the completeness of the machine, for if it is to be a standard one, instead of being adapted only to a special use, there is in the first case many expensive additions that may be made which can be omitted in a special machine. It will, therefore, be assumed in this example that a special machine is to be constructed to perform a particular duty only.

The nature of the work to be performed consists in cutting away the metal between the teeth of the rack, leaving a perfect outline for the teeth, and as this shape of the teeth cannot well be obtained by adjustment of the tools, it must be attained by the shape of the tools. As the shape of the tools must be maintained, and the cross section of the displaced metal is not too great, we at once conclude that the shape of the tools should be a profile of the space between the teeth, and the whole cut away at one setting or one operation. By the application of principles laid down in a former place in reference to cutting various kinds of material, it is decided to use reciprocating or planing tools, instead of rotary or milling tools to cut away the metal in the present case.

Next, we come to movements which consist in a reciprocating cutting movement, a feed movement to graduate the cutting, and a longitudinal movement of the rack with means to graduate the pitch of the teeth.

The reciprocating cutting movement being but four inches or less, a crank is obviously the best means to produce this motion, and as the movement is transverse to the rack which may be long and unwieldy, it is equally obvious that the cutting motion should be given to the tools instead of the rack.

The feed adjustment of the tool being intermittent and the amount of cutting edge that acts continually varying, this movement should be performed by hand so as to be controlled at will by the sense of feeling. The same rule applies to the adjustment of the rack for spacing, which being intermittent and irregular as to time, should be performed by hand. The speed of the cutting movement from established data we know should not exceed from sixteen feet to twenty feet a minute, and that a belt two and one-half inches wide must move two hundred feet a minute to propel an ordinary metal cutting tool, so that the crank movement must be increased by gearing until this speed of the belt is reached. This will furnish the general speed of pulleys and gear wheels.

Next comes arrangement; in this the first matter to be considered is the convenience of manipulation. The cutting should be within easy view, so as to be watched, and horizontally, to be more easily watched. The operator has to keep his hand on the adjusting or feed mechanism, which is about twelve inches above the work, and it follows that if the cutting level is four feet from the floor, and the feed handle five feet from the floor, the arrangement will be convenient for a standing position. It may also be assumed that as the work requires continual inspection and hand adjustments, it would be a proper arrangement to overhang both the supports for the rack and the cutting tools, placing them, as we may say, outside the machine, to secure convenience of access and allow inspection. The position of the cutting bar, crank, connections, gearing, pulleys and shafts, will assume their respective places from the obvious conditions arising from the position of the operator and the work.

Next in order are strains; as the cutting is the source of the strains, and as the resistance offered by the cutting tools is as the length of the acting edge, we find in this case that while all other conditions have pointed to a small machine we have here a new one that calls for large proportions. In displacing the metal between the teeth of three-fourths inch pitch, the cutting edge or the amount of surface acted upon is equal to a width of one and one-half inches; it is true, the displacement may be but small at each cut, but the strain, as remarked before, is rather to be predicated upon the breadth of the acting edge, and we find here conditions that create strains equal to the average duty of a large planing machine. This strain radiates from the cutting point as from a centre, falls on the supports of the

work with a tendency to force it from the framing, acts between the rack and the crank shaft bearing, through the medium of the tool, cutter bar, connection, and crank pin, and in various directions and degrees that may be very well defined in making a drawing. Besides this cutting strain, there are none of importance. The tension of the belt, the side thrust in bearings, the strain from the angular thrust of the crank, and the end thrust of the tool, are all insignificant, and while not to be lost sight of, need not to have much to do in questions of proportion or special arrangement.

In the strains we find data for special arrangement, which is quite a distinct matter from general arrangement, the latter being governed by the conveniences of manipulation. Special arrangement deals with and determines the shape of framing, following the strains throughout the machine. In the present case we have a cutting strain which will be assumed as equal to one ton exerted between the bracket or jaws that support the work and the crank shaft. It follows that between these points the metal in the framing should be disposed in as direct a line as possible, but as the frame cannot follow this line but must go below it, provision must be made to resist flexion by a deep section vertically, and parallel with the cutting motion.

Lastly, proportions; having estimated the cutting force required at one ton, which will serve for illustration, although less than the actual strain in a machine of this class, we proceed upon this to base proportions, beginning with the tool shank, and following back through the adjusting saddle, the cutting bar, connections, crank pins, shafts, and gear wheels to the belt. Starting again at the tool, or point of cutting, following back through the supports of the rack, the jaws that clamp it, the saddle for the graduating adjustment, the connections with the main frame, and so on to the crank shaft bearing, giving dimensions to each piece that is sufficient to withstand the strains without deflection or danger of breaking. These proportions cannot, I am aware, be brought within the rules of ordinary practice by relying upon calculation alone to fix them, and no such a course is suggested; calculation may aid, but cannot determine proportions in such cases; besides, symmetry, which cannot be altogether disregarded, often modifies the form of cast iron framing.

I have in this way indicated a methodical plan of proceeding to generate a design, as far as words alone will serve, beginning with certain premises to define the purpose to be attained, and then pro-

ceeding to consider in consecutive order the general character of the machine, mode of operation, movements and adjustments, general arrangement, strains, special arrangement, and proportions.

With a thorough practical knowledge of machine operation and an acquaintance with existing practice, an engineer proceeding upon this plan will, if he does not overlook some of the conditions, generate machine designs that will remain without much modification or change so long as their purpose, to which it is directed, remains the same.

Perseverance is an important trait to be cultivated in first efforts to generate designs; it takes a certain amount of study to understand any branch of mechanism, no matter what natural capacity may be brought to bear. Mechanical operations are not learned intuitively, and are always surrounded by many peculiar conditions that must be learned seriatim, as we may say, so that it is only by an untiring perseverance at one thing that there can be any hope of improving it by new designs.

The learner who goes from gearing and shafts to steam and hydraulics, from machine tools to cranes and hoisters, will not accomplish much. It is a good plan to select an easy subject at first, one that admits of a great range of modification, and if possible, one that has not assumed a standard form of construction. Bearings and supports for shafts and spindles, is perhaps one of the best.

In bearings for shafts the strains are easily defined, while the pivotal support, vertical and lateral adjustment, and lubrication of bearings and symmetry of supports and hangers will furnish material for endless modification, both as to arrangement and mechanism.

In making designs never use any references except what is carried in the mind. The more familiar a person is with machinery of any class, the more able he may be to prepare designs, but not by measuring and referring to other people's plans. Dimensions and arrangement are in this way carried into a new drawing, even by the most skilled, without their being at the time conscious of it; besides, it is by no means a dignified matter to collect other people's plans and by combination and modification to produce new designs. This may be, at first, an easy plan to acquire a certain kind of proficiency, but will most certainly hinder an engineer from ever rising to the dignity of an original designer. The custom of using references destroys confidence and inculcates habits of thought and a want of originality that when once acquired are not easily got rid of.

Symmetry, as an element in designs for machinery, is one of those unsettled matters that can only be determined in connection with particular cases. I may, however say, that in all engineering implements and manufacturing machinery of every kind, there should be nothing added for ornament, or that has no correlation with the functions of the machinery.

Modern engineers of the better class are so thoroughly in accord in this matter in both opinion and practice, that it hardly requires to be mentioned; but it will be no disadvantage to the learner who intends to devote his time to mechanics to commence by cultivating a contempt for whatever has no useful purpose. Of existing practice it may be said, that in what may be called industrial machinery, the amount of ornamentation met with is inversely as the amount of engineering skill that was employed in preparing the designs.

Perhaps a safe rule will be to assume that all machinery that is used and seen by the skilled, should be devoid of ornament, and that machinery that is publicly seen by the unskilled, should have some ornament in its composition. If there is to be any rule, this would seem to be a proper one, and accords with modern practice, for, by common consent, steam fire engines, water works engines, sewing machines, and other work of this class that falls mainly under the inspection of the unskilled, is usually arranged with more or less ornamentation.

Ornament, when attempted, should never be carried further than graceful proportions, and the arrangement of framing should follow as nearly as possible the lines of strain. Extraneous ornamentation, such as detached filagree work of iron, or painting in colors, is so repulsive to the taste of the true engineer and mechanic that there is but little use in arguing against it.

INVENTION.

The relation between invention and the engineering arts, and especially between invention and machines, will warrant a short review of the matter here; or even if this reason was wanting, there is a sufficient one in the fact that one of the first aims of an engineering apprentice is to "invent" something, and as the purpose is, so far as possible, to say something upon each subject in which the beginner has an interest, invention must not be passed over. It has been the object, this far, to show that machines, processes, and mechanical manipulation generally may be systematized and generalized to a

greater or less extent, and that a failure to reduce mechanical manipulation and machine construction to certain rules and principles can only be ascribed to a want of knowledge, and not to any inherent condition or principle that prevents such a solution. This same proposition is applicable to invention, with the difference that invention, in its true sense, may admit of a more perfect generalization than even machines and processes.

By the term invention, as applied to mechanical improvements, is not meant chance discovery, a construction that is commonly placed upon the term, but deductions wrought out from certain principles or premises that have been proved and acknowledged; the results attained by the application of intelligent research and experiment, as distinguished from what may be called discovery; in short, demonstration, which may be applied to any improvement that is not the result of chance.

In the sciences that rest in any degree upon physical experiment, like chemistry, discovery and experiments without a definite purpose, may be a proper kind of research, and may, in the future, as it has in the past, lead to great and useful results; but in mechanics the matter is different; the demonstration of the conservation of force, and the relations between force and heat, has supplied the last link in a chain of principles that may be said to comprehend all that we are called upon to deal with in ordinary mechanics, and there remains but little hope of developing anything new or useful by discovery alone. The time has been, and has not yet passed away, when even the most unskilled thought their chances of inventing improvements in machinery were almost equal with that of the engineer and skilled mechanic, but this has been changed in late years, and new schemes are now weighed and tested by scientific analysis, that is often more reliable than actual experiments, unless the experiments are scientifically performed. The veil of mystery that an ignorance of the physical sciences had thrown around mechanics has been cleared away, and so far has mechanical superstition, if the term may be allowed, and chance discovery disappeared, that many of our best modern engineers regard their improvements in machinery but the exercise of their profession, and hesitate about asking for protective grants that will secure an exclusive use of that which another might and often does demonstrate whenever circumstances called for such improvement. There are, beyond doubt, new articles of manufacture to be discovered, and perhaps improvements in machinery that will be

proper subject matter for patents; improvements that in all chance would not be made for the term of a patent except by the inventor; but such cases are very rare, and it is fair to assume that unless an invention is one that could not be regularly deduced from existing data, and one that would not, in all probability, have been made for a long term of years by any other person than the inventor, then the inventor can have no natural right to exclusive use that will not infringe that of others.

It is not, however, the intention to discuss patent law now, even to judge what benefits have in the past, or may in the future be gained to technical industry by the patent system, but what I do wish to do is to impress the engineering apprentice with a better and more dignified appreciation of his calling than to confound it with chance invention, and thereby destroy that confidence in positive results which characterizes modern mechanical engineering. I would also have him guard against the loss of time and effort that is often expended in searching after inventions for the object of gain, reminding him that such schemes are always predicated upon an assumed ignorance on the part of others that often turns out a mistake.

Let the apprentice invent or demonstrate all that he can, the more the better, but let it be according to some system, and with a proper object. Never spend time in groping in the dark after an object of which no definite conception has been formed, nor after any project that is not to fill an ascertained want; that is, never make an invention and then have to hunt up a use for it, but start methodically, as a bricklayer builds a wall, as he mortars and sets each brick as he goes along, so qualify each piece or movement that is added to the mechanical structure, so that when done, the result may be useful and enduring.

As remarked, every attempt to generate anything new in machinery should be commenced by ascertaining a want for the improvement; first find a fault in what exists, or is already known, and set out with a definite object in view. Study the general principles upon which this fault is to be remedied, or upon which the want may be met, and then "fill in" the mechanism like the missing link in a chain. These propositions, stated in this way, will no doubt fail to convey the full meaning intended, and I will assume an example to render this systematic plan of inventing more plain, choosing the valve movement of steam hammers as a new subject.

Presuming that the apprentice has read what was said of steam hammers in another place, or is from other sources already familiar with the uses and general construction of hammers, let us suppose that steam hammers, with the ordinary automatic valve action, to be well known and understood, so far as those that give an elastic or steam-cushioned blow. Next, suppose that by analyzing the nature of the blow given by hammers of this class, either by mathematical deductions, theoretical inference, or by experiment, it has been demonstrated that dead blows, where the hammer comes to a full stop in striking work, to be more effectual in certain kinds of work, and that steam hammers would be improved by being arranged to operate upon this principle. This would constitute the first stage of the invention, by demonstrating a fault in existing hammers, and a want of certain functions that would, if added, improve them.

Proceeding from these premises, the first thing should be to examine the principles and plans of existing valve gear, to see where this want of functions lies, and to gain the aid of suggestions that the existing mechanism may offer, also to see how far the appliances in use may become a part of any new system that is to be applied.

By examining the rebounding hammers it will be found that the valve is connected to the drop by means of links, that produce a coincident movement of the piston and valve, and that the movement of one is contingent upon and governed by the other. It will be seen that these connections or links are capable of extension in their length, to alter the relative position of the piston and valve, thereby regulating the range of the blow, but still the movement of the two is reciprocal or in unison. Reasoning inductively, not discovering or inventing, it may be determined that to secure a stamp or dead blow of the hammer head, the valve must not open or admit steam beneath the piston until the blow is completed and the hammer has stopped. Here occurs one of those mechanical problems that especially require logical solution. The valve must be moved by the drop, there is no other moving mechanism to give motion to it; besides, the valve and drop must be connected, to insure coincident action, but the valve requires to move when the drop is still. Proceeding still inductively, it is clear that a third agent must be introduced, some part that is moved by the drop, and in turn moves the valve, but so arranged that this intermediate agent may *continue to move after the hammer-drop has stopped.*

(To be continued.)

Chemistry, Physics, Technology, etc.

ON THE EFFECT OF ACID ON THE INTERIOR OF IRON WIRE.*

By Professor Osborne Reynolds, M. A.

It will be remembered that at a previous meeting of this society, Mr. Johnson exhibited some iron and steel wire in which he had observed some very singular effects produced by the action of sulphuric acid. In the first place the nature of the wire was changed in a marked manner, for although it was soft charcoal wire it had become short and brittle; the weight of the wire was increased; and what was the most remarkable effect of all was that when the wire was broken, and the face of the fracture wetted with the mouth, it frothed up as if the water acted as a powerful acid. These effects, however, all passed off if the wire were allowed to remain exposed to the air for some days, and if it were warmed before the fire, they passed off in a few hours.

By Mr. Johnson's permission, I took possession of one of these pieces of wire and subjected it to a farther examination, and from the result of that examination I was led to what appears to me to be a complete explanation of the phenomena. I observed that when I broke a short piece from the end of the wire the two faces of the fracture behaved very differently—that on the long piece frothed when wetted and continued to do so for some seconds, while that on the short piece would hardly show any signs of froth at all. This seemed to imply that the gas which caused the froth came from a considerable depth below the surface of the wire, and was not generated on the freshly exposed face. This view was confirmed when on substituting oil for water I found the froth just the same. These observations led me to conclude that the effect was due to hydrogen, and not to acid, as Mr. Johnson appeared to think, having entered into combination with the iron during its immersion in the acid, which hydrogen gradually passed off when the iron was exposed. It

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was obvious, however, that this conclusion was capable of being further tested. It was clearly possible to ascertain whether or not the gas was hydrogen, and whether hydrogen penetrated iron when under the action of acid. With a view to do this I made the following experiments.

First, however, I would mention that after twenty-four hours I examined what remained of the wire, when I found that all appearance of frothing had vanished and the wire had recovered its ductility, so much so that it would now bend backwards and forwards two or three times without breaking, whereas on the previous evening a single bend had sufficed to break it. I then obtained a piece of wrought iron gas pipe, 6 inches long and $\frac{3}{8}$ inch external diameter, and rather more than 1-16 inch thick; I had this cleaned in a lathe both inside and outside; over one end I soldered a piece of copper so as to stop it, and the other I connected with a piece of glass tube by means of india-rubber tubes. I then filled both the glass and iron tubes with olive oil and immersed the iron tube in diluted sulphuric acid which had been mixed for some time and was cold. Under this arrangement any hydrogen which came from the inside of the glass tube must have passed through the iron. After the iron had been in acid about five minutes small bubbles began to pass up the glass tube. These were caught at the top and were subsequently burnt and proved to be hydrogen. At first, however, they came off but very slowly, and it was several hours before I had collected enough to burn. With a view to increase the speed I changed the acid several times without much effect until I happened to use some acid which had only just been diluted and was warm; then the gas came off twenty or thirty times as fast as it had previously done. I then put a lamp under the bath and measured the rate at which the gas came off, and I found that when the acid was on the point of boiling as much hydrogen was given off in five seconds as had previously come off in ten minutes, and the rate was maintained in both cases for several hours. After having been in acid some time the tube was taken out, well washed with cold water and soap so as to remove all trace of the acid; it was then plunged into a bath of hot water, upon which gas came off so rapidly from both the outside and inside of the tube as to give the appearance of the action of strong acid. This action lasted for some time, but gradually diminished. It could be stopped at any time by the substitution of cold water in place of the hot, and it was renewed

again after several hours by again putting the tube in hot water. The volume of hydrogen which was thus given off by the tube after it had been taken out of hot acid was about equal to the volume of the iron. At the time I made these experiments I was not aware that there had been any previous experiments on the subject; but I subsequently found, on referring to Watts' "Dictionary of Chemistry," that Cailletet had in 1868 discovered that hydrogen would pass into an iron vessel immersed in sulphuric acid. See *Comp. Rend.* lxvi., 847. The facts thus established appear to afford a complete explanation of the effects observed by Mr. Johnson.

In the first place, with regard to the temporary character of the effect, it appears that the hydrogen leaves the iron slowly even at ordinary temperatures—so much so that after two or three days' exposure I found no hydrogen given off when the tube was immersed in hot water. With regard to the effect of warming the wire—at the temperature of boiling the hydrogen passed off 120 times as fast as at the temperature of 60 deg. Also when the saturated iron was plunged into warm water the gas passed off as if the iron had been plunged into strong acid; so that we can easily understand how the hydrogen would pass off from the wire quickly when warm, although it would take long to do so at the ordinary temperatures. With regard to the frothing of the wire when broken and wetted, this was not due, as at first sight it appeared to be, simply to the exposure of the interior of the wire, but was due to warmth caused in the wire by the act of breaking. This was proved by the fact that the froth appeared on the sides of the wire in the immediate neighborhood of the fracture, when these were wetted, as well as the end; and by simply bending the wire it could be made to froth at the point where it was bent. As to the effect on the nature and strength of the iron, I cannot add anything to what Mr. Johnson has already observed. The question, however, appears to be one of very considerable importance, both philosophically and in connection with the use of iron in the construction of ships and boilers. If, as is probable, the saturation of iron with hydrogen takes place whenever oxidation goes on in water, then the iron of boilers and ships may at times be changed in character and rendered brittle in the same manner as Mr. Johnson's wire, and this, whether it can be prevented or not, is at least an important point to know, and would repay a further investigation of the subject.

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